

WEST AFRICAN CACAO RESEARCH INSTITUTE



ANNUAL REPORT

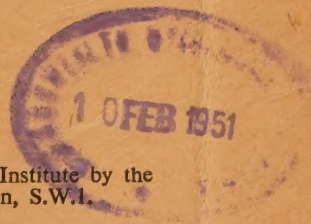
April, 1948 to March, 1949

TAFO, GOLD COAST

Published on behalf of the West African Cacao Research Institute by the
Crown Agents for the Colonies, 4, Millbank, London, S.W.1.

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WEST AFRICAN CACAO RESEARCH INSTITUTE.

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WEST AFRICAN CACAO RESEARCH INSTITUTE.
ANNUAL REPORT : 1st APRIL, 1948 TO 31st MARCH, 1949.

I. POLICY AND ORGANIZATION.

SWOLLEN-SHOOT DISEASE.

Of the many research activities of the Institute those concerning swollen-shoot disease of cacao have received most prominence. The Institute's recommendations for controlling the spread of the disease by cutting out infected trees met with so much opposition that the Commission of Enquiry into disturbances in the Gold Coast considered that this method of disease control should be subjected to review by an independent panel of pathologists. The Institute did not become aware of this recommendation till the Report of the Commission had been prepared.

From a list of pathologists submitted by the United Nations Food and Agriculture Organization Dr. G. H. Berkeley (Canada), Dr. Walter Carter (U.S.A.) and Professor E. Van Slogteren (Holland) were selected. They arrived in the Gold Coast in October, 1948, and examined in great detail the Institute's work on the virus diseases of cacao, vectors and alternative hosts. Their findings, published in December, 1948, fully supported the Institute's recommendation of control by cutting out diseased trees. In their report it was suggested that the staff and facilities of the Institute should be increased—the approved establishment has never yet been filled—and that the Chemical Industry might make material contribution to the Institute's programme by evolving arboricides to facilitate the destruction of diseased cacao trees and insecticides capable of application on a field scale to reduce the number of vectors.

No time has been lost in consulting the Chemical Industry. Representatives of the Colonial Insecticide Committee and of the Association of British Chemical Manufacturers visited Tafo in February, 1949. Means by which Industrial resources can best be utilised to assist in solving our problems are now being carefully studied. Modern developments in organic chemistry have long reached a stage where fundamental research on the new arboricides and insecticides requires facilities not available in West Africa.

It cannot be stressed too often that the best scientific advice confirms the urgent need for first destroying the major reservoir of swollen-shoot virus, *i.e.*, diseased cacao trees. Other adjuncts of control such as an attack on the vector mealybugs and the destruction of alternative forest tree hosts of the virus are additional to the policy of cutting out and not a substitute for it. Though there are still factors concerning swollen-shoot disease which require further investigation our knowledge on the salient points is considerable. Thus our recommendations for the control of swollen-shoot are based on a comprehensive understanding of the viruses concerned, the field vectors and their biology and alternative hosts of the virus. Moreover, we now have detailed information on the relationship between virus and

vector—the length of feeding time necessary for a mealybug to pick up the virus and the length of time the virus stays in the mealybug. At the moment research on swollen-shoot has outrun the capacity of the Gold Coast to make full use of the results.

The publicity given to swollen-shoot in the press of many countries has led to a spate of suggested cures by private individuals. Many of these cures so confidently advised are based on soil improvement. Our work has, however, shown conclusively that the incidence of swollen-shoot is in no way dependent on the type or fertility of the soil. The cacao farmers in the Gold Coast and Nigeria are indeed fortunate in having their pockets protected from those who might so easily relieve them of money by the sale of costly quack remedies.

MANAGING COMMITTEE.

The Managing Committee met at Tafo in December, 1948, and February, 1949. Apart from matters of administration and finance the Committee paid particular attention to the provision of scholarships, improvement in the terms of service for specialist staff and to the vexed question of making known to the public the Institute's work. The implementation of the UNO pathologists' recommendation concerning the Institute's research programme was deemed impossible unless sufficient specialist staff were available. Experience over the past years had shown that adequate staff was not attracted by the current terms of service, and the Committee therefore agreed that improved terms were essential if the right type of specialists were to be attracted to the Institute.

SCHOLARSHIPS.

The Institute has offered two types of scholarships; one type to increase the technical proficiency of the Junior Staff, the other to give academic training to Africans for them to obtain the professional qualifications necessary for appointment to the Specialist Staff. Up to the present the African in West Africa has had little opportunity of showing whether he has a flair for scientific research and the Institute's decision to make the experiment of having African research specialists will be of great interest. At the same time the function of the Institute is cacao research and not politics; it would therefore be unwise to press too far the Africanization of the research staff until the African's research capabilities are proved.

The response to the offer of a five year scholarship in the United Kingdom to obtain the necessary professional training was most disappointing in 1948. No suitable candidate was forthcoming from Nigeria and of the three applicants from the Gold Coast none had the minimum qualification. Two such scholarships were offered early in 1949. Applicants with the minimum qualification—Intermediate Science—comprised one from the Gold Coast and five from Nigeria. These candidates were interviewed by the Government Scholarship Boards and no candidate was considered suitable for a W.A.C.R.I. Scholarship.

Three of the Institute's Junior Staff are now receiving technical training in the United Kingdom.

STAFF CHANGES.

In the approved permanent senior staff establishment of 20 there were five vacancies as at 31st March, 1949. Mr. N. F. Robertson, Virus Pathologist, left to accept appointment as lecturer at Cambridge University, and Mr. E. W. Alther, Agronomist, joined the Institute's staff. During a period of several months when there was no W.A.C.R.I. Agronomist at Tafo the Agricultural Department rendered great assistance by posting to the Institute a member of the Department's senior staff.

Mr. A. F. Posnette, Senior Pathologist, has accepted secondment to East Malling Research Station. He has given outstanding contributions to research on cacao in West Africa and his loss—even if temporary—to the Institute will be keenly felt. It will be remembered that Mr. Posnette discovered the virus nature of swollen-shoot disease and his pioneer work on strains of the virus, vectors and alternative hosts represent only one facet of his research activities. His name will be associated with selection and breeding of local cacao types and with the recently introduced varieties of *Theobroma cacao* and different species of *Theobroma*. These introductions were arranged by Mr. Posnette in 1944 when he visited the West Indies specifically for that purpose. He also discovered an important pollinating agent of cacao in the Gold Coast.

In the Junior Establishment, vacancies have been caused by the promotion of Mr. T. S. Adoo, Technical Assistant to the post of Inspector of Produce, Department of Agriculture, and by the acceptance of a Gold Coast Government Scholarship by Mr. A. A. Laryea, Technical Assistant.

CONSTRUCTION.

Good progress has been made in the construction programme over the past twelve months. The construction schedule, brought up to date from last year's Annual Report is as follows:—

				Approved.	Completed.	Under Construction.
Administrative Block	...	...		1	—	1
JUNIOR STAFF :						
Four-Roomed Houses	...			10	—	1
Three-Roomed Houses...	...			50	6	11
Two-Roomed Double Units	...			62	62	—
Recreation Hall	...	...		1	—	—
SENIOR STAFF :						
Bungalows	...	...	...	13	9	3

Pipe-borne Water Supply.

Unexpected difficulties in preparing the rock base for the dam wall have been encountered, but these have been overcome and tenders for construction will be offered shortly. Certain essential material, mainly in connection with valves, the filtration plant and service reservoir is still awaiting delivery. Some 70 acres of catchment area have been acquired.

Timber has been short at rising prices, but construction material generally has been in fair supply.

The Gold Coast Electrical Department has stationed an officer at Tafo to supervise the instalment of electricity to the new senior and junior staff quarters, and to other buildings.

FINANCE.

The Institute is deeply indebted to the Cocoa Marketing Boards of the Gold Coast and Nigeria for the allocation of £690,000 and £310,000 respectively to the Institute's Funds. These amount to some £1,800,000 as at 31st March, 1949, and are invested in trustee stock by the Crown Agents. The interest from these investments is insufficient to meet the Institute's annual recurrent expenditure and it is therefore necessary to liquidate certain holdings as the need arises. The approved estimate of recurrent expenditure for 1948/49 was £92,010 and actual expenditure was £75,091. The saving is again largely accounted for by inability to fill the Senior Staff establishment.

Since 1st May, 1948, the Institute has met local payments from its bank account in the Gold Coast and expenses incurred overseas are paid by the Crown Agents from the Institute's London account. There has, therefore, been no need to borrow money from the Gold Coast Government. The Institute's revenue was augmented by the sale of some 52 tons of cacao from the station realizing a price of £6,257.

PUBLIC RELATIONS.

At its third and fourth meetings the Managing Committee expressed concern over the lack of knowledge which exists among those interested in cacao in the Gold Coast and Nigeria about the activities of the Institute. The annual and quarterly reports of W.A.C.R.I. are essentially technical and are written as a record of research accomplished and in hand. It is appreciated that they are for the most part incomprehensible to the lay reader as, indeed, are most technical reports of scientific research organizations. A brief summary in each quarterly report gives the main items of interest in such terms as might be comprehensible to the public, but it is obvious that these summaries have not filled the function that was expected of them.

For the first two or three years of the Institute's existence it was the policy to seek no propaganda until research results were

obtained. The time has now come when the Institute has results of great practical importance and the wider these are made known the better. But publicity of research which has not reached the stage of definite practical conclusions is always fraught not only with misunderstanding but positive danger. For example, laboratory tests have shown that mealybugs, the vectors of swollen-shoot can be easily destroyed. If publicity were given to this it seems almost inevitable that a section of people would jump to the conclusion that there would be no need to cut out diseased trees.

It was therefore suggested that an officer of the Gold Coast Public Relations Department should visit W.A.C.R.I. monthly to learn at first hand what was going on; by using his own judgment he would interpret and give wide publicity to those facets of the work which he considered of most interest.

DEMONSTRATIONS.

Though W.A.C.R.I. propaganda through the written word leaves much to be desired, there has been a keen interest shown by parties of farmers visiting the Institute's station at Tafo. The Agricultural Department has posted an African Senior Officer at Tafo for the specific purpose of conducting these parties round the station. Farmers are invited to attend by Agricultural Survey Officers working in the field; transport to Tafo is arranged and a meal provided. On these occasions only *bona fide* farmers are invited in parties of not more than 15 farmers at a time. These visits have been of almost daily occurrence, and there is no doubt that they have proved beneficial not only in giving visible evidence of successful control of swollen-shoot but also in showing capsid control by D.D.T. painting on young cacao, different methods of growing the crop and, most appreciated of all, new varieties of cacao. The world over, seeing is believing, and the Institute welcomes a continuation of these farmers' visits and the assistance of an Agricultural Survey Officer in demonstration.

IMPROVED SEED DISTRIBUTION.

Certain of the recently introduced varieties of cacao new to West Africa have already shown their superiority in early bearing at Tafo over the common West African type. At five years old yields have been in the region of ten times greater than those from the West African type planted at the same time in the same plot.

Samples of beans from these newly introduced varieties appear similar to those which form the bulk of the African crop and have been sent for commercial assessment to chocolate manufacturers. The Manufacturers' reports are awaited.

In co-operation with the Agricultural Departments of Nigeria and the Gold Coast—these Departments are the sole agents for the distribution of improved cacao planting material—several thousand basket seedlings are available for planting out during 1949.

LONDON CACAO CONFERENCE.

This Conference was held in September, 1948, at the invitation of the Cocoa Chocolate and Confectionary Alliance Limited. The Institute was represented by Messrs. West, Nicol, Benstead and Strickland. The discussions disclosed a keen interest taken in the part that research has to play in the production of raw cacao. In spite of anticipated expansion of cacao growing in parts of the world other than West Africa, it was considered that the Gold Coast and Nigeria would still maintain their position as leading sources of supply.

Once again the Conference permitted most useful exchange of information and views among those from distant territories interested in the manufacture and production of cacao.

A full report of the proceedings was speedily printed and published.

VISITORS.

The year has seen a great increase in the number of visitors to the Institute. Apart from those specifically interest in swollen-shoot disease, and these include the Watson Commission, the UNO Scientists and the representatives of the Chemical Industry, there have been visits from staff of the Imperial College of Tropical Agriculture, Trinidad, from manufacturing interests in the United Kingdom, from the U.S.A. State Department, the Liberia Corporation, and from the research station Turrialba, Costa Rica. There have been, too, the usual visits from many in the Gold Coast and Nigeria. Particularly welcome were representatives of the Nigerian press and on another occasion of leading Nigerian cacao farmers. Welcome, too, was the visit of French Scientists from the Ivory Coast.

This is all highly desirable, and indeed inevitable where it is remembered that the future of the West African Cacao Industry is so dependent on the work done at the Institute. But it must be admitted that the day to day work of the specialist staff has been hampered by these visits. Important visitors naturally wish to go into greater detail, or to have a broader picture given them than can be provided by the Department of Agriculture's demonstrator, whose job it is to conduct parties of farmers and school children round the Station. As with research stations throughout the world the fact must be accepted that part of a specialist's duty will be to explain his work to visitors. This is by no means always a one sided affair since visitors often produce a new idea or can put a specialist into contact with someone carrying out similar work in other parts of the world. This has certainly been the Institute's happy experience during the past year.

TOURS.

Apart from the normal tours of W.A.C.R.I. staff to Nigeria, Mr. J. West, Deputy Director, visited Liberia to gain first hand experience of the cacao problems there. His visit was at the request of the U.S. State Department. It is obvious that the Institute should maintain as close a contact as possible with the technical developments of cacao growing throughout West Africa.

At the invitation of the Sierra Leone Government, Mr. West's Liberian tour was extended into Sierra Leone.

The Cameroons Development Corporation asked for a visit by one of the Institute's staff to advise on cacao production. This request has been complied with and Mr. West, who was in charge of the Cameroons estates during the war, went there in March, 1949.

A further request, this time in connection with Sudden Death of Cloves, was made by the Zanzibar Government for a visit to Zanzibar and Pemba by Mr. A. F. Posnette, Senior Pathologist. There is reason to believe that Sudden Death of Clove trees is a virus disease. The Institute acceded to this request and Mr. Posnette was absent for some eight weeks.

Invitations to the Inter-American Cacao Conference at Turrialba, Costa Rica in March, 1949, had unfortunately to be refused owing to pressure of work, but it will be desirable for a member of the Institute's staff to visit both that research station and the West Indies cacao research station in Trinidad in the near future.

SCIENTIFIC ASSISTANCE.

The Institute is indeed fortunate to have had so much generous assistance from individuals and research organizations in other parts of the world. The Commonwealth Institute of Entomology both directly and through its contacts with Entomologists in other countries has devoted considerable attention to our problems of insect classification. The Commonwealth Institute of Biological Control, Canada, is assisting with the introduction of parasites of mealybugs. Rothamsted Experiment Station and London University are endeavouring to obtain electron micrographs of the swollen-shoot virus and the Statistical Department of Rothamsted has gone to considerable lengths in assisting the Institute with the Statistical examination of insect populations. The Colonial Insecticides Committee continues to keep the Institute well informed on new insecticides and their methods of application.

The British Food Manufacturing Industries Research Association has given valuable advice on our investigations into fermentation and the chemical constituents of cacao beans. That Association has greatly helped in expediting the delivery of apparatus from England. The Institute is further indebted to the cacao sub-committee of the Colonial

Agricultural and Forestry Research Advisory Committee for the helpful interest taken in all aspects of the research programme.

Offers of assistance have been received not only from scientists. "Cures" for swollen-shoot, as already stated, have been promised by a number of methods ranging from soil treatment, one of which includes watering the ground early each morning with water from a large green balloon-like bottle, to the application of nascent chlorine to the trees, or the injection of trees with Cooper's Sheep dip.

ACKNOWLEDGEMENTS.

The technical part of the report which follows is prepared by the research staff. As so much of the work in progress here reported is the result of co-operative effort not only within divisions but between divisions, it would be invidious to mention authors by name. It is, therefore, with great pleasure that the Director acknowledges the preparation by them of the sections which follow.

II. VIRUS RESEARCH.

SWOLLEN-SHOOT AND OTHER VIRUS DISEASES OF CACAO.

Nigerian Cacao Viruses.

(a) *A New Virus.*

Budwood collected in June, 1948, from infected trees in the recently discovered outbreak at Alaparun in Nigeria, has transmitted a new cacao virus (1R) to the test plants at Tafo. In the acute phase, this virus causes a red pigmentation over the whole lamina of the young leaf; later, this pigment may be reduced to a mottle, but it is always diffused over a greater area of the leaf than is the red mottle caused by some cacao viruses. The only other symptom is the development of small transparent lesions, which sometimes become necrotic, and resemble those of the Asalu virus (1S). The Alaparun virus is transmissible by *Pseudococcus njalensis*, Laing but probably not by *Ferrisia virgata*, Ckll.

(b) *Virulence of Nigerian Viruses.*

An experiment was started in January, 1948, to compare the virulence of the Nigerian viruses with that of some Gold Coast viruses. Ten N38 (T38) seedlings, all of the same age, were infected by patch grafting with each of the viruses listed in Table 1. Measurements were taken of the size of each leaf and the length of each new flush. It can be seen from Table 1 that the Ilesha virus is the most virulent. A complicating factor in this experiment is that N38 progeny shows much more variation in vegetative characters than does the ordinary Amelonado. Some of the N38 seedlings appear to be quite tolerant.

TABLE 1.

EFFECT OF NIGERIAN VIRUS ON ONE YEAR'S GROWTH OF 10 SEEDLINGS INFECTED WITH EACH VIRUS IN JANUARY, 1948.

Virus.	Mean Number of flushes per plant.	Mean No. of leaves per flush.
Ilesha	2.7	3.3
New Juaben (G.C.)	5.1	3.9
Olanla 1	3.8	4.3
Olanla 2	5.1	4.3
Offa Igbo 1	4.2	4.4
Offa Igbo 2	5.4	4.6
Akarán	5.5	4.6
Asalu	4.6	5.2
Konongo (G.C.)	5.0	5.8
Control (Healthy)	4.6	6.3

Inter-relationships of Viruses.

Cross-protection tests to study the relationships between the many cacao viruses have shown few to be closely related. While serological work remains impracticable with cacao viruses, the only reliable method of proving relationship between two viruses is to find out if one can produce its characteristic symptoms in plants previously infected with the other virus.

Although this work is not yet complete, it can be said that, in addition to the relationships mentioned in the 1947-48 report—

- (a) no other cacao virus shows any close relationship to either virus 1C (Kpeve) or 1M (Mampong);
- (b) the Kongodia (Ivory Coast) virus 1X is probably related to virus 1A (New Juaben).

Virus-Host Relationships.

- (a) *A newly-discovered locus of infection in the plant.*

Previous work has shown that cacao viruses can be transmitted by vectors from leaf, green stem, bark, lateral root and pod tissues of infected plants. Seed transmission has never been obtained and it has been assumed that the viruses are unable to build up in seeds developing on diseased trees. Recent work has shown, however, that virus is transmissible from the testae of such seeds. Seeds were taken from immature pods with the rounded contours and mosaic symptoms of virus 1A; the embryo and mucilage were removed from within each testa and mealybugs (*P. njalensis*) placed in the cavity. After two days, the mealybugs were transferred to cacao bean test plants at rates of 10 adults or 30 crawlers per bean. Thirteen testae were thus

examined for virus infection and a total of 37 cacao beans infested from them. Three cases of virus transmission were obtained, from two testae.

(b) *Transmission rates after vector infestation of germinating and fresh beans.*

It was thought that virus build-up might be more favoured in a germinating bean, as a result of the enzymic processes associated with active growth, than in the apparently more dormant bean, freshly removed from the ripening pod. This hypothesis was tested by a simple comparative experiment replicated four times. Virus source plants were infested at the time of the first growth flush. The vector was *P. njalensis* and the rate of application to the test plants, five crawlers per bean. The results are given in Table 2.

TABLE 2.
TRANSMISSION RATES FOLLOWING INFESTATION OF
GERMINATING AND FRESH BEANS.

Replication.	Germinating Beans.		Fresh Beans.
	Period of germination.	Transmission Rate.	Transmission Rate.
1 	3 days	17-34	30-34
2 	2 days	20-40	15-40
3 	3 days	16-31	20-31
4 	4 days	19-34	24-34
Total		72-139	89-139

The analysis of variance, worked out after transformation of the percentage transmissions to degrees, indicated no significant difference resulting from the treatments, the error variance being larger than that for treatments.

Studies on the Virus 1A Complex.

Comparison in transmissibility between attenuated and virulent strains of Virus 1A.

It has already been reported (Ann. Rep., W.A.C.R.I., 1947-48, pp. 18-20) that attenuated virus 1A was readily transmissible by vectors from symptom-bearing leaves of seedlings infected with that strain. The transmission rates were comparable with those obtained from virulent virus 1A-infected seedlings at similar stages of development. There was, however, a greatly decreased transmission rate from symptomless leaves of attenuated virus 1A-infected seedlings, and, except during a short acute phase and occasional symptom

recurrences, attenuated strain infected seedlings are, in fact, symptomless. Comparisons in transmissibility have been carried on, and some recent results, which corroborate the earlier ones, are given in Table 3. Seedlings were tested in sets usually of six pairs in which one member of each pair had been infected in the bean stage with attenuated strain A, and the other with virulent A. The seedlings of each set were given identical treatment following the infection feeding of the bean. On reaching the test stage, seedlings were treated by the removal of all leaves except those belonging to the appropriate flush which was then infested with virus-free adults of *P. njalensis*. The subsequently produced crawlers were the vectors used. The receptor plants were infested in the bean stage, the rate being five crawlers per bean.

TABLE 3.

INFECTION RATE IN RECEPTOR PLANTS AFTER
INFECTION FEEDING OF THE VECTORS ON GROWTH
FLUSHES OF SEEDLINGS CARRYING ATTENUATED OR
VIRULENT VIRUS 1A.

Set.	Strain.	Aggregate No. of Seedlings.	Vector feeding site on virus source plants.		Total trans- missions.	Percentage.
			Growth flush.	Symptoms.		
1 ...	Att.	3	1st	+	35-75	46.7
	Vir.	3	1st	+	39-70	55.7
2 ...	Att.	5	1st	+	23-151	15.2
	Vir.	5	1st	+	54-174	31.0
3 ...	Att.	6	1st	+	120-249	48.2
	Vir.	6	1st	+	141-237	59.5
4 ...	Att.	6	2nd	—	0-99	—
	Vir.	6	2nd	+	91-146	62.3
5 ...	Att.	5	2nd	—	3-353	.85
	Vir.	5	2nd	+	42-146	28.8
6 ...	Att.	6	2nd	—	2-180	1.1
	Vir.	6	2nd	+	25-134	18.7
7 ...	Att.	7	3rd	—	0-290	—
	Vir.	7	3rd	+	120-224	53.6

Further work is necessary to test the significance of the relatively lower transmission rates observed from attenuated A-infected plants

in the symptom-bearing phase. The results in Table 3 suggest that attenuated virus 1A is almost unavailable to vectors fed on the leaves or stems of symptomless flushes. This would be of practical importance if protection of trees by attenuated strains were ever resorted to as a method of disease control.

Virus Resistance.

Two types of resistance trials with virulent virus 1A have been carried out, one with rooted cuttings of local yield selections of Trinitario and Amelonado types, and the other with seedlings of the new introductions.

In the cuttings trials 58 clones were tested; 20 plants of each clone were each infested with 30 infective insects. There were varying rates of infection from 10 per cent. to 100 per cent. and a second trial is now in progress to compare the five most resistant with the five most susceptible clones.

The progenies of the new introductions have been tested in the bean stage, and those showing resistance are now being re-tested at about six months old. The progenies of the Upper Amazon types formed by the cross Nanay x Parinari have shown considerable resistance to infection by vector feeding on the cotyledon. In seven experiments using 10 insects per plant, the mean rate of infection in the Amelonado controls was 8.7 ± 0.83 out of 20, and in the Nanay x Parinari types, 3.85 ± 0.85 ; the difference between these means is significant at the one per cent. point.

Rate of Spread and Effect on Yield.

Unrestricted natural spread of virus 1A in the demonstration area has now been recorded for $3\frac{1}{2}$ years. By March, 1949, 85 per cent. of the trees in the area were diseased; in Table 4, the spread during three years is tabulated.

TABLE 4.
INFECTED AND MORIBUND OR DEAD TREES IN $8\frac{1}{4}$ ACRES,
1945-1948.

	Original total of mature trees.	August, 1945		August, 1946		August, 1947		August, 1948	
		Infec- ted.	M. or D*.	Infec- ted.	M. or D*.	Infec- ted.	M. or D*.	Infec- ted.	M. or D*.
Number	4,636	1,450	361	2,134	671	2,967	1,457	3,717	2,192
Percent- age ...	—	31	8	46	14	64	31	80	47

Although the number of trees becoming infected each month is now falling, as few healthy trees remain, the percentage of healthy

* Moribund or dead trees, included in number of infected trees.

trees becoming infected has steadily increased. Table 5 shows an increase in the rate of spread which indicates that the number of trees infected each month would be increasing if the plot had no boundaries.

Replanting has been done in the outbreaks, following the present farming practice, and the cacao seedlings are making good growth. A census taken in March, 1949, showed ten of these seedlings to be infected. This reflects the position in farms where replanting has been done without the removal of infected trees.

TABLE 5.
ANNUAL RATE OF INFECTION.

Year.	Number of healthy trees remaining.	Number of new infections.	Per cent.
1945/6 ...	3,186	682	21
1946/7 ...	2,504	835	33
1947/8 ...	1,669	750	45

The yield from the plot has continued to decline, despite the over-average crop harvested during 1948 from healthy trees.

1945	...	...	41,771	Pods harvested.
1946	...	...	33,716	" "
1947	...	...	24,569	" "
1948	...	...	20,048	" "

MEALYBUG SPECIES AND CACAO VIRUSES.

All the species of the *Pseudococcidae* obtainable in sufficient numbers have been tested with some or all of 16 cacao viruses. Twelve species have been found to transmit one or some of these viruses:—*Pseudococcus njalensis*, Laing; *P. citri* (Risso); *P. bukobensis*, Laing; *P. brevipes* (Ckll.); *P. concavocerarii*, James; *P. longispinus*, T-T; *P. sp.*, near *masakensis*, Green; *P. sp.*, near *celtis*, Strickland (H6424); *P. sp.*, near *gahani*, Green (H6421); *Ferrisia virgata*, Ckll.; *Phenacoccus sp.* H6418; and *Paraputo ritchiei*, Laing.

No vector has yet been found for the Asalu (Nigeria) cacao virus (1S). The other viruses tested, which include eight from the Gold Coast, five from Nigeria and two from the Ivory Coast are all transmitted by *P. njalensis* but fall into two groups according to whether they are transmissible by *F. virgata* and not by *P. longispinus*, or *vice versa*.

ALTERNATIVE HOST PLANTS OF CACAO VIRUSES.

Work on the host range of cacao viruses has resulted in the discovery of only one host not mentioned in the 1947-48 W.A.C.R.I. report—*Erythropsis Barteri* K. Schum. None of the plants tested in families other than the Bombacaceae and Sterculiaceae has proved to be susceptible to the cacao viruses used.

Seedlings of *Cola chlamydantha* K. Schum have been shown to be susceptible to all the Western Province (Gold Coast) viruses with which they have been tested, and also to two Ivory Coast viruses and to virus 1J from Bosomtwe, but they appear to be resistant to virus 1A.

Field testing of wild plants in swollen-shoot outbreaks has proved that *Ceiba pentandra* Gaertn. the silk-cotton tree, can be a field carrier of two of the swollen-shoot viruses, one in Nigeria and one in the Gold Coast. A naturally infected seedling of *Cola cordifolia* R. Br. has also been found, at Tafo.

SWOLLEN-SHOOT CONTROL.

The campaign to eradicate swollen-shoot from the Institute's lands was intensified in September, infection from surrounding cacao farms having become more acute, and symptoms more easily recognised during the heavy flush period. More detailed supervision was possible with the appointment of a second Agronomist who was put in charge of the work. Suspected trees on the Old Station were recorded from October onwards and trees in contact with diseased trees were removed on the New Acquisition, with a resultant drop in infection from December onwards.

Table 6 gives the monthly figures for the Old Station and Table 7 those for the New Acquisition.

OLD STATION.

TABLE 6.
NUMBER OF NEW OUTBREAKS AND DESTROYED TREES
ON THE OLD STATION.

Month.	New Outbreaks.	Trees Destroyed.		Total.	Trees.	
		New Outbreaks.	Old Outbreaks.		Diseased.	Suspect.
April 1948 ...	6	17	40	57	57	—
May ...	2	7	15	22	22	—
June ...	6	6	28	34	34	—
July ...	2	3	24	27	27	—
August ...	7	15	20	35	35	—
September ...	7	32	50	82	82	—
October ...	6	18	86	104	104	—
November ...	5	7	21	28	25	6*
December ...	3	4	17	21	16	7*
Jan. 1949 ...	5	11	31	42	33	9
February ...	5	6	31	37	32	5
March ...	6	8	12	20	18	2
Total ...	60	134	375	509	485	29

* These suspects developed symptoms and were cut out in the month following that in which they are recorded.

The table confirms that the infection continues in several new outbreaks and that reinfections in old outbreaks are still high. Flushing periods at the beginning of the rainy season and in September and October are significant for disclosing infected trees.

NEW ACQUISITION.

The campaign to eradicate swollen-shoot disease on the New Acquisition was intensified during the second half of the year by the removal of trees which were suspected of carrying the disease.

More positive recognition of disease symptoms on the flush period of September and November was reflected on the greater number of trees cut out during those months.

Records of swollen-shoot control are given in Table 7.

TABLE 7.

CACAO CUT OUT ON THE SQUARE MILE, 1948/49.

Standing cacao April 1st, 1948 (acres)	259.5
Diseased trees cut out April 1st, 1948 to 31st March, 1949	7,486
Contact trees cut out April 1st, 1948 to 31st March, 1949	3,489
Suspect trees cut out April 1st, 1948 to 31st March, 1949	875
Area represented by disease and suspect and contact trees (acres)	16.6
Area cleared for building and other purposes (acres)...	17.0
Standing cacao March 31st, 1949 (acres)	225.9

The comparatively light reinfection of young cacao trees continues and data are given in Table 8.

TABLE 8.

INCIDENCE OF SWOLLEN-SHOOT ON YOUNG CACAO.

Station.	Date plant- ed.	Approx. No. of plants.	Diseased Plants.							
			1942 /43.	1943 /44.	1944 /45.	1945 /46.	1946 /47.	1947 /48.	1948 /49.	Total
Akwadum ...	1942	28,000	—	1	2	2	2	47	17	71
Koransang ...	1945	15,000	—	—	—	3	31	72	20	126
Kukua ...	1945	50,000	—	—	—	—	1	23	30	54
Nankese ...	1945	35,000	—	—	—	—	1	2	1	4
Adonkwanta	1945	56,000	—	—	—	—	12	60	17	89
Tafo (Old Station) ...	1940- 1948	90,000	—	—	—	—	1	2	5	8

As in previous years infection on the sub-stations has been almost entirely on seedlings near the boundaries.

THE BIOLOGY AND BIONOMICS OF THE MEALYBUG VECTORS OF SWOLLEN-SHOOT.

Work during the year has been concentrated entirely on the biology and bionomics of the mealybug vectors of swollen-shoot.

This section of the report reviews the progress over the last four years, with a summary of the more important points that have been elucidated.

Twelve species of pseudococcid mealybugs are now known to transmit cacao viruses. At the end of 1945 three species only were known:—*Pseudococcus njalensis*, Laing, *P. citri* (Risso), and *Ferrisia virgata* (Ckll.). Between that time and the present day, it has been shown that *P. bukobensis*, Laing, *P. longispinus*, T-T, *P. concavocerarii*, James, *P. brevipes* (Ckll.), *Paraputo ritchiei*, Laing, three undetermined *Pseudococcus* species, and one species of *Phenacoccus* are able to transmit the viruses. There remain species of the genera *Farinococcus*, *Formicococcus*, *Tylococcus*, and *Coccidella* to be tested.

Of this assemblage of species, *P. njalensis* is far and away the most important species on cacao in the Gold Coast. Field collections on an organized basis have shown that the species dominance is of the order *P. njalensis* 200, *P. citri* 1·5, all other species 0·5, and for this reason the first named species has received most attention. In the rest of this report, *P. njalensis*, *P. citri*, and "all other pseudococcine species occurring on cacao" are taken as three vector groups for purpose of comparison. These groups are discussed below in relation to their habits and biology.

Habitat.

All species are essentially arboreal, though most have been taken from time to time on various ground flora, such as members of the Araceae, Bromeliaceae, Solanaceae, etc. *P. njalensis* is negatively phototropic, and prefers cracks in the bark of the host tree, old capsid lesions, or the underside of pod petioles as feeding sites. When, as it usually is, this species is ant attended, its preferred feeding sites include the green shoots and new growth at the top of the canopy, but only so long as it is sheltered by ant carton tents. *P. citri* and the other species are not so selective in feeding site. These species tend to prefer young growth such as pods or leaf stalks, and are not ant attended to the same extent as *P. njalensis*, nor so strongly negatively phototropic.

Conclusion 1:—The virus vectors are essentially arboreal feeders, and occur in their greatest numbers in the canopy layer of the host tree.

Host Preferences.

There is little specificity in host preference. Exceptions include *Farinococcus loranthei*, Strickland which is invariably associated with *Loranthus* spp., and occurs as free-living colonies on a host tree only as sub-colonies from a mistletoe growing on that tree. *P. njalensis* itself is almost invariably associated with the myrmecophyte *Canthium glabriflorum* Hiern (Rubiaceae), and in cacao farms where this plant is common (occurring at more than three to the acre), it may account for more than half of the *P. njalensis* on those farms. As far as is known at present, *C. glabriflorum* is not a virus host, and its infestation by vectors is only of importance in so far as it is a reservoir in which the mealybugs can breed up and disperse to the surrounding cacao.

P. citri has the widest host plant range of any of the species, with the possible exception of *F. virgata*, which is anyhow found more often on plants other than cacao—particularly on members of the leguminous genera *Lonchocarpus*, *Leucaena* and *Gliricidia*. There are indications, particularly with *P. njalensis*, that mature plants are preferred to young seedlings as hosts. The mean infestation rate for *P. njalensis* on immature cacao (girth less than eight inches), is just over 20 per cent., and for mature cacao, over 38 per cent. These differences are significant at $p = 0.01$, and appear to be consistent. Approximately 40 per cent. of the Sterculiaceae plants apart from cacao that have been examined have been infested with one or other of the mealybug species with which we are concerned and this figure compares with 52 per cent. of the Rubiaceae (including *C. glabriflorum*), 46 per cent. of the Bombacaceae (mostly *Ceiba pentandra*), and 45 per cent. for *Theobroma cacao*.

Conclusion 2: Vector host plant specificity is of little significance in so far as about 45 per cent. of the plants making up the flora of the average Gold Coast cacao farm are infested with one or other of the cacao feeding pseudococcids.

Dispersal.

The first and second larval instars ("crawlers") of the cacao pseudococcids are dispersed by wind currents in periods of dry weather. Dispersal of the older nymphs and young adults is usually by their own volition after ecdysis—moulting appears to induce a desire for a fresh feeding site—and this might account largely for the rapid spread of swollen-shoot in a closed canopy cacao farm. Unassisted adult or nymphal migration over the litter after a cacao tree has been felled does take place, but evidence to hand indicates that most of such migrants are devoured by predators before they have moved more than a few (6-8) feet. Ant assisted migration in these circumstances is more important, and cases are on record of successful establishment of mealybugs by Crematogasterine ants on trees 18 feet away from the original point of dispersal. Dispersal by man, when pods are taken to a central dump for breaking and bean extraction, is a fact which undoubtedly occurs, but no data are available to indicate the extent of this practice.

Conclusion 3 : Vector dispersal takes place by wind, by ant assistance, by individual initiative, and by man. Canopy migration could be effectively stopped by breaking the canopy and destroying the connecting links between neighbouring trees. Terrestrial migration is of little importance.

Life History.

" Other species " and *P. citri* are oviparous, and eggs take 3-6 days to hatch. They are laid in a well-formed ovisac of white wax filaments. The time period from hatching to egg laying is about five weeks for *P. citri* (nymphal life about 35 days), about six weeks for *F. virgata* (nymphal life about 30 days), and about six weeks for *P. njalensis* (nymphal life about 25 days). The period from copulation to egg laying is longest in the case of *P. njalensis*, and this is to be expected since this mealybug is ovoviviparous and produces eggs which are fully mature and hatch immediately on extrusion.

Conclusion 4 : For each of the vector species studied, there appear to be 6-8 generations per annum in the Gold Coast. Field studies have shown that there is no period in the year when vector colonies cannot be found, though they are apparently (particularly with *P. citri* and " other species ") more common and hence easier to find, in the dry than the wet season.

Parasites and Predators.

The vectors are attacked by a number of predatory and parasitic insects in the field. To date, 15 species of Hymenopterous parasites, one ecto-parasitic dipteran, two species of predatory beetles, and two species of mites that are probably ecto-parasitic, have been bred from vector colonies collected in the field in the Tafo region. There are no numerical data available on predator incidence. So far as *P. njalensis* is concerned, the predatory species are relatively unimportant since the attendant ants effectively drive them away from their mealybug " cattle ". Even the internal parasite rate is low with regard to *P. njalensis*, varying between 1.6 per cent. and 5.4 per cent. with a mean of just over three per cent., of adult mealybugs parasitized. The variation has been found to depend partly on which ant species is attending a given colony, and on the mean density of mealybugs in that area. It is to be hoped that, if the ant association can be broken, the parasite species already present locally will be able to effect a far better degree of control on their mealybug hosts. That this may be so is indicated by the fact that *P. citri*, which is not often ant attended, has a mean adult parasitization rate of about 8 per cent., i.e., higher than *P. njalensis*, and particularly remarkable in view of the very low density of *P. citri*.

Conclusion 5 : The effect of local parasites and predators on the most important vector species is small. This is almost certainly due to ant " protection " of the mealybugs, and if the ant association can

be broken, it seems likely that a much better degree of control will result.

BIONOMICS.

The following salient points have emerged as a result of the routine sampling of vector populations over the past two years:—

Density is very variable. Vector populations of from 6,000 to 200,000 per acre occur within a given five-acre block. Similarly, percentage infestation varies, an area with over 80 per cent. of the cacao trees infested with vectors may be adjacent to an area with less than 10 per cent. of trees infested.

This variation in density is largely the result of ant associations between the species concerned and their mealybug "cattle". In this respect, ants of the genus *Crematogaster* are correlated with mealybug density to a highly significant extent ($r. = + 0.9150$ with 9 DF). There is clear evidence of negative associations between ants of the genera *Crematogaster*, *Oecophylla*, and *Macromischoides*, and hence between mealybugs and the two last named genera. It is now clear that an area with high mealybug and *Crematogaster* density can be contained by an adjacent area heavily infested with *Oecophylla longinoda*, Latreille, and with a very low vector density. It is probable, then, that this ant acts as a factor restricting the spread of swollen-shoot in areas where its normal density is high.

O. longinoda is almost invariably associated with one or other of the cacao scale insects of the genus *Stictococcus*. Up to the present, these scale insects are regarded as causing no economic damage to cacao, though they are believed to do a certain amount of damage (decreased yields from infested pods), in the Belgian Congo. Whether an artificial encouragement of *O. longinoda* as a means of mealybug control would lead to the evolution of the scale insects into pests in their own right would be a matter for investigation.

There is evidence to indicate that there are annual changes in feeding site, at least so far as *P. njalensis* is concerned. When there are no pods on the trees, this mealybug is largely (84 per cent. of the individuals) restricted to the canopy, particularly on the twigs. As pods mature, they are colonized by mealybugs to an increasing extent until October, when as many as 40 per cent. of the pods in a given area may be infested. Subsequently, the pod infestation rate drops until, in February, only about 0.5 per cent. of the pods still on the trees are infested. Many mealybugs are removed with the harvested pods, and this accounts for an apparent annual low density at the end of the year. During the dry season, January to March, colonies thrive and increase so that, by the start of the rains in April, mean density is more normal.

Vector density is associated with virus spread and there are highly significant differences in virus incidence in areas of low and

high vector density, though this does not mean to say that a lot of virus is always associated with high vector density, or that a high vector density invariably means a lot of virus. It is clear that, if no virus is present, it cannot be transmitted. From observations extending over two years, a correlation of $r. = + 0.9366$ with 39 D.F. between mealybug incidence and virus incidence has been obtained. This is, however, open to confirmation in the light of recent advances in the statistical treatment to be given to plant disease gradients. Unfortunately no data are available to show the effect of vector control on virus incidence.

Tree felling is an expensive way of estimating pest densities, and a correlation has recently been obtained ($r. = + 0.8860$ with 9 D.F.), between percentage of pods infested and percentage of trees infested, in a given area. It is likely, then, that this will prove to be a valuable and simple method of evaluating vector incidence during the harvesting season in relation to control methods. There is hope that branch sampling as distinct from whole tree sampling, will shortly be possible; thanks are due to workers at the Rothamsted Statistical Laboratory for assistance rendered in this respect.

An adequate technique has been evolved for the routine sampling of mealybugs on seedling cacao, and this has been applied to determine the effect on mealybug density of a routine 2.5 per cent. D.D.T. painting technique. No significant drop in infestation on the treated plot was apparent after two years painting.

Conclusion 6: Vector density is so variable, and tied up with so many related factors, that control methods based solely on the incidence of virus in a given area are likely to prove more expensive than efficacious. Any form of control, biological or chemical, must be applied in swollen-shoot areas where vector density is known to be heavy. Since, in a 20-acre block of cacao, only $1\frac{1}{2}$ acres may be dangerously infested with vectors (i.e., may have 50 per cent. of the trees infested with mealybugs and ants), it is this $1\frac{1}{2}$ acres that must receive the heaviest insecticidal treatment, or in which the parasites or predators should be liberated. Simple survey methods for determining vector density are well advanced.

CHEMICAL CONTROL OF MEALYBUGS.

Several of the new insecticides including HETP (hexaethyl tetraphosphate) and E.605 or Parathion (diethyl-p-nitrophenyl thiophosphate) have been shown to be very effective against mealybugs and scale insects generally in other parts of the world and laboratory tests on these and other insecticides have been commenced.

A home-made spray-tower was used and, although this showed up mass differences between the insecticides being used, the spray nozzle was not sufficiently accurate for detailed work on insect toxicities. A "Potter" spray tower is being built and full investigation of the action of insecticides will be undertaken when it is delivered.

Sufficient data have been accumulated to show that even when the mealybugs are not protected by carton nests they are extremely difficult to kill with liquid insecticides unless sufficient wetting agent is incorporated to ensure that the insects are thoroughly wetted.

Much more successful results have been obtained by using insecticidal dusts in a laboratory dust tower. Uniform deposits are readily obtained and quite a few dusts have been shown to be very effective against *P. njalensis*.

The time to obtain a kill of the test insects is remarkably lengthy. Dusted insects show few deaths 24 hours after dusting although many are in a moribund condition, the only movement being spasmodic twitching of the legs and antennae. Crawlers born during this time are usually dead or die soon afterwards and little or no feeding is apparent when the test insects are transferred to cacao beans. The control insects usually show a very low mortality over the 96 or 120-hour test period. The following results of an actual test will demonstrate the above facts:—

TABLE 9.
EFFECT OF INSECTICIDAL DUST ON *P. NJALENSIS*.
Test insects Adult *P. njalensis* collected in
the field.
Amount of dust used 0.5 gm.
After treatment Insects kept on cacao beans in
gauze covered tins.

Insecticide used.	*Corrected percentage dead after			
	24 hours.	72 hours.	96 hours.	120 hours.
E.605 (0.75%)	12.5	95	100	100
Nicotine (3%)	5.0	27.5	41	73
Benzene Hexachloride (5%) ...	0.0	5.3	25	26
DDT (10%)	0.0	47.5	90	91

It will be seen that a very low percentage of E.605 dust is more rapidly effective against *P. njalensis* than much higher percentage of other insecticides.

Comparison of Susceptibility of P. njalensis and F. virgata to E.605 and Nicotine dusts.

It was early apparent that these two species of mealybug did not react in the same way when treated with these two dusts and comparative tests were run.

* True percentage mortality calculated from Abbots formula $\frac{C-t}{C} \times 100$ where C is the percentage of live insects in the control and t the percentage of live insects in the test.

TABLE 10.

SUSCEPTIBILITY OF *P. NJALENSIS* AND *F. VIRGATA* TO E.605 AND NICOTINE.

Test insects Adult *P. njalensis* and adult *F. virgata*.
 Amount of dust used 0.25 gms.
 After treatment Insects kept on cacao beans in gauze covered tins.

Insecticide.	Species.	*Corrected percentage dead after			
		24 hours.	48 hours.	72 hours.	96 hours.
E.605... .. 0.3%	<i>P. njalensis</i> ...	28	54	66	91
	<i>F. virgata</i> ...	22	73	73	90
Nicotine 3.0%	<i>P. njalensis</i> ...	22	37	60	61
	<i>F. virgata</i> ...	3	3	9	9

From the above table it will be seen that E.605 dust is effective against both species whereas *F. virgata* appears to be resistant to nicotine. This fact has been confirmed by other experiments.

There can be no doubt that E.605 is an extremely potent insecticide against the mealybug vectors of swollen-shoot but it must be remembered that the above tests were carried out on unprotected insects and that to apply this insecticide successfully in the field requires the development of suitable machines. Several new types of machine are becoming available which give promise of being applicable to the conditions in the cacao farms.

There is one grave drawback to the use of E.605 and that is its high mammalian toxicity. Operators must be fully protected against this chemical and the utmost cleanliness is essential with protective clothing as it is likely that the chemical can be absorbed through the skin. Masks, gloves and goggles are definitely advisable and these are, of course, extremely irksome in the tropics.

However, development of related but less toxic chemicals is proceeding and the direct chemical control of the vectors of swollen-shoot now appears to be possible especially in local areas as, for instance, in the trees surrounding treated outbreaks. Such applications would probably reduce the rate of spread and render retreatment much easier.

* True percentage mortality calculated from Abbots formula $\frac{C-t}{C} \times 100$ where C is the percentage of live insects in the control and t the percentage of live insects in the test.

Chemical Control of the Ant Attendants of Mealybugs.

P. njalensis is almost entirely dependant on certain ant species for transport from one feeding site to another, for protection from predators and for protection from inclement weather. Now it is obvious that if this close association could be broken by killing a large proportion of the attendant ants, a measure of control of the mealybug would be attained. There are associated with cacao, however, many other ants which are probably beneficial so that wholesale slaughter of all the ants is not to be desired.

Part of the Macromischoides Block at Tafo is being used to see if any selective control is possible by chemical means. This block is divided up into $\frac{1}{4}$ -acre plots each having seven full rows of twenty-one plants alternating with rows having only eleven plants. Seven such plots are being used and each full row is used for a replicated series of tests. The treatments are :—

1. Control.
2. Grease band " A ".
3. Grease band " B ".
4. Lower part of the stem painted with 2.5 per cent. D.D.T. emulsion.
5. Lower part of the stem painted with 5 per cent. D.D.T. emulsion.
6. Monthly spraying with 15 per cent. dispersible E.605.
7. Ten per cent. D.D.T. dust spread around the base of the tree. Before treatment each tree was examined and samples of any ants found were collected for identification. The presence of mealybugs was also recorded.

Regular examinations will be made over an extended period.

Systemic Action of the Newer Insecticides.

Several of the newer phosphorous containing insecticides have been shown to possess systemic properties. When sprayed on plants or watered into the surrounding soil they are picked up into the plant system and prove toxic to certain insects which subsequently attack the plant.

Preliminary results on cacao with E.605 have not been hopeful but a series of samples of other insecticides is awaited when a much fuller investigation of this phenomenon will be undertaken with special reference to cacao.

THE BIOLOGICAL CONTROL OF THE MEALYBUGS.

In August, 1948, on returning from a visit to East Africa, A. F. Posnette brought to Tafo pupae of an Encyrtid parasite, a race of *Anagyrus kivuensis*, Compère, which has been of considerable value in the biological control of *Pseudococcus kenya*, Le Pelley on coffee in Kenya. In November, the living culture was handed over to the Division of Entomology for maintenance and mass rearing prior to liberation.

This parasite has successfully attacked *P. njalensis*, *P. citri* and *P. brevipes* in laboratory tests at Tafo, and has not been recorded as indigenous to the Gold Coast, though other representatives of the genus are known to be present. In Kenya it has been shown to be an efficient searcher and to be little affected by the presence of ants attendant on the mealybug hosts.

It is hoped that liberations of this species will be made shortly, and plans for the introduction of other parasites which have been of value in controlling various species of *Pseudococcus* have been made and will be put into effect as soon as adequate apparatus is available.

III. CAPSID RESEARCH.

POPULATION STUDIES.

Routine Collections.

The daily collection of capsids from cacao around Tafo was terminated as it was agreed that sufficient data has been accumulated over four years to determine with reasonable accuracy the seasonal fluctuation in population numbers.

Collections continued at Owena until the end of March, 1949, when they too were terminated.

TABLE 11.
Collection figures at Owena 1948-49.

Month.	<i>S. singularis</i>		<i>D. theolroma</i>		Pods per 100 trees.
	Per 100 Pods.	Per 100 Trees.	Per 100 Pods.	Per 100 Trees.	
April, 1949	1.4	2.8	0.02	0.06	320
May	0.8	2.0	0.03	0.01	504
June	0.9	2.1	0.04	0.03	598
July	1.1	3.1	0.09	0.04	680
August	2.2	6.1	0.03	0.09	690
September	1.9	4.5	0.24	0.60	591
October	2.0	3.7	0.27	0.54	366
November	2.6	3.5	0.24	0.37	176
December	3.3	4.2	0.13	0.31	142
January, 1949	4.7	4.0	0.70	0.75	20
February	3.9	2.9	0.80	0.70	25
March	1.7	1.1	0.10	0.11	66

Helopeltis sp. on cacao.

Helopeltis sp. collected during the routine collections have shown that this species, which is principally known as a pod feeding insect, is in fact, relatively common on the vegetative parts of older trees and on seedlings. The figures collected amplify observation in the field where *Helopeltis* sp. appears to be developing a taste for the vegetative parts of cacao trees.

TABLE 12.
Collection figures at Tafo 1948-49.

Month.	<i>Helopeltis</i> sp.		
	Per 100 Pods.	Per 100 Trees.	Per 100 Seedlings.
April, 1948	0.56	0.63	1.4
May	0.41	0.45	1.4
June	0.47	0.55	2.4
July	0.56	0.98	3.5
August	1.60	1.8	4.0
September	0.91	0.97	3.7
October	0.52	0.49	2.3
November	0.71	0.26	0.9
December	0.97	0.43	1.1
January, 1949	0.40	0.10	0.05
February	0.32	0.02	0.00
March	0.11	0.01	0.04

Thus *Helopeltis* sp. was present in fair numbers on pods and on trees throughout the year. On the seedlings examined, *Helopeltis* sp. was absent during only one month (February, 1949).

BIONOMICS OF *S. SINGULARIS* ON CACAO AND ALTERNATIVE HOSTS.

Table 13 gives comparative figures of life-cycles of *S. singularis* on several possible alternative hosts and on cacao.

TABLE 13.
LIFE CYCLE OF *S. SINGULARIS*.

Host.	Incubation period in days.	Nymphal life in days.	Total.	Percentage of nymphs completing life-cycle.
<i>Sterculia rhinopetala</i> ...	17	23	40	41
<i>Ceiba pentandra</i>	18	23	41	100*
<i>Cola togoensis</i>	18	26.5	44.6	89
<i>Cola cordifolia</i>	17	26.2	43	69
<i>Bombax</i> sp.	17	29	46	100†
<i>Cistanthera papaverifera</i> ...	17.4	22.4	39.8	64
W. A. Amelonado Cacao ...	17.5	23.4	40.6	70
T.38 Cacao	18	22.2	40	72
Average	17.4	24	42	

* Only three records.

† Only two records.

Bryocoropsis sp. prob. *laticollis* on alternative hosts.

This capsid which is common on cacao pods in the Gold Coast has not yet been recorded on this type of food in Nigeria. One record was obtained of this species feeding on a T-38 cacao seedling which was shaded by *Uvariadendron* sp., a plant on which it is regularly recorded in Nigeria.

In March, 1948, a specimen was collected from *Anonidium manii*, Engl. & Diels (Anonaceae) and since then many more specimens have been recorded on this plant.

Full records of *Bryocoropsis* sp. prob. *laticollis* with the feeding site are given below. In many cases the *A. manii* and *Uvariadendron* sp. were growing in or in close proximity to cacao.

TABLE 14.
INCIDENCE OF *BRYOCOROPSIS*.

Host.				Flowers.	Fruit.	Shoots.	Total.
<i>Anonidium manii</i>	...			44	77	43	164
<i>Uvariadendron</i> sp.	...			10	50	46	106
Cacao	...	...	...	0	0	1	1

As this Nigerian species of *Bryocoropsis* appears to be loathe to transfer its attention to cacao, a long series of specimens has been mounted so that a specific determination can be obtained from the British Museum (Natural History).

CAPSID PHYSIOLOGY AND BEHAVIOUR.

The work is still in the observational stage, and the results which are reported, were obtained by observation of individual specimens of *D. theobroma*, cultured in 1-inch diameter glass tubes on pieces of cacao chupon. The food material was changed daily and the number of lesions recorded. In as many cases as possible, the nymph or adult was weighed immediately after a moult. Several records of lesion number and weight increase were obtained from capsids caged on pods.

Replications of this experiment using cacao shoots of different degrees of maturity shows no observable difference, and neither did replicates kept in permanent darkness by means of a black paper cover over the tube.

The number of lesions made per day during the 5th instar rises slightly towards the middle of the instar, as shown by the following figures (for a six day instar).

TABLE 15.

FEEDING LESIONS, *D. THEOBROMA* (5TH INSTAR).

Day 			Mean Number of Lesions.					
			1	2	3	4	5	6
5th instar	Female		22.44	26.00	26.20	25.10	24.33	13.44
	Male	...	21.01	22.86	24.40	24.93	22.28	13.80

The figures for the 4th instar are as follows :—

TABLE 16.

FEEDING LESIONS, *D. THEOBROMA* (4TH INSTAR).

Day 				Mean Number of Lesions.			
				1	2	3	4
4th instar nymph			...	20.92	23.54	22.92	21.37

A few individuals (two out of 15 females and one out of 15 males) made a large number (35 to 50) of lesions per day and a correspondingly large number per instar. The reason for this has not yet been investigated, but these individuals differed significantly in this respect from the rest of the population.

TABLE 17.

NUMBER OF LESIONS PER INSTAR.

Female	{ Normal	...	...	137.4 ± 19.48
	{ Aberrant	...	...	243.25 ± 14.85
Male	{ Normal	...	...	125.5 ± 21.26
	{ Aberrant	...	...	233.0

With regard to the weight increase, the increase per lesion (i.e., per feed) during the instar has been used for comparison. The results show a significantly greater figure for females than for males, and for pod feeding against chupon feeding. The figures are significant at below the one per cent. point.

TABLE 18.

WEIGHT INCREASE PER FEED.

Females	{ Chupons	...	...	0.1026 mgm.
	{ Pods	...	...	0.1492 mgm.
Males	{ Chupons	...	...	0.0659 mgm.
	{ Pods	...	...	0.1111 mgm.

EXTENSIVE OBSERVATION PLOTS.

In the previous Annual Report figures are quoted from the Mealybug Population experiment, which show the difference in the intensity of capsid feeding on fans and chupons. As the lesions caused by the different species cannot be differentiated, no estimate is possible of the part played by each species.

Actual counts of capsids, as in the Observation Plots, permit a comparison of the distribution of *S. singularis* and *D. theobroma* to be made, both between different types of cacao, and between the different parts of the individual tree. The following estimations are based on the totals of 18 months' observations on the five capsid pockets and the three healthy cacao plots which comprise the Extensive Observation Plots. The difference in distribution illustrated below have been tested statistically on the original data.

The proportion of *D. theobroma* observed on pods is smaller than the proportion of *S. singularis* on pods, which is surprising in view of past statements that *D. theobroma* in old cacao is confined to pods. Table 19 shows the percentage of *S. singularis* and *D. theobroma* found on pods, both for the healthy cacao plots and for the capsid pockets.

TABLE 19.

PERCENTAGE OF *S. SINGULARIS* AND *D. THEOBROMA* ON PODS.

	Healthy.	"Pockets."
<i>S. singularis</i> ...	24	13
<i>D. theobroma</i> ...	8	9

Furthermore, *D. theobroma* on the vegetative phase of the tree is more restricted to chupons than is *S. singularis*. Table 20 shows the percentage of the stem population of both species on chupons in the two types of cacao.

TABLE 20.

PERCENTAGE OF *S. SINGULARIS* AND *D. THEOBROMA* ON CHUPONS.

	Healthy cacao.	"Pockets."
<i>S. singularis</i> ...	58	82
<i>D. theobroma</i> ...	72	89

Consequent upon these preferences, it would be expected that *D. theobroma* is more confined to capsid pockets than is *S. singularis*. This is found to be so, 79 per cent. of the number of *S. singularis* observed being in pockets as opposed to 90 per cent. *D. theobroma*.

The overall picture appears to be that *S. singularis* is a more widely distributed species than is *D. theobroma* as it can utilize a wider range of food, and adapts itself readily to the nature of the cacao. *D. theobroma* in mature cacao is closely restricted to the chupon growth of degraded cacao.

CAPSID/ANT RELATIONSHIP.

Healthy trees, in an area otherwise badly damaged by capsids, are often associated with the presence of certain ant species, particularly *Macromischoides aculeatus*, Mayr.

This association is illustrated in Table 21 which gives the numbers of trees showing three categories of damage and their distribution between three classes—trees with *Macromischoides aculeatus*, Mayr., trees with *Oecophylla longinoda*, Catr. and trees with neither. The capsid damage is classified on the following scale:—

Less than 1 per cent. twigs damaged = Absent.

Not more than 20 per cent. twigs damaged = Slight.

More than 20 per cent. twigs damaged = Severe.

TABLE 21.

ASSOCIATION OF ANTS WITH CAPSID DAMAGE.

Damage.				Neither ant.	Ant Species.	
					<i>Oecophylla</i> .	<i>Macromischoides</i> .
Absent	...	...	...	13	12	12
Slight	...	...	...	188	168	61
Severe	...	...	...	180	76	10
Total	...	...	...	381	256	83

A test of independence gives a value for $\chi^2 = 56.378$, the theoretical value of χ^2 at $P = 0.01$ being 13.277. The association of ants with trees only slightly damaged or not damaged at all is obvious.

The above classification is based essentially on old capsid damage, but counts of fresh lesions give a measure of new damage. The test has been repeated using fresh lesions as the criterion, the average number of lesions per stem being obtained and the damage classified as follows:—

No lesions = damage absent.

1—10 lesions = damage slight.

10 or more lesions = damage severe.

TABLE 22.

ASSOCIATION OF ANTS WITH RECENT CAPSID DAMAGE.

Damage.				Neither ant.	Ant Species.	
					<i>Oecophylla.</i>	<i>Macromischoides.</i>
Absent	...	...	...	70	87	25
Slight	...	...	...	250	213	46
Severe	...	...	...	17	10	2
Total	...	...	...	337	310	73

The new value of χ^2 is 9.058, which is now less than the theoretical value for $P = 0.05$, which is 9.488. The reduction in the individual totals is particularly marked with *Macromischoides*, and less so with *Oecophylla*.

One may conclude therefore that the association of *Macromischoides aculeatus* with healthy trees is mainly one of colonization of healthy trees after the surrounding trees prove unsuitable by virtue of the capsid damage. *Oecophylla longinoda* appears to exercise a greater direct influence on capsids, but in neither case is there any striking control of fresh capsid damage.

MACROMISCHOIDES FIELD EXPERIMENT.

The cacao in this experiment continues to grow well and in March, 1949, just two years after planting, flowers appeared on twenty-five seedlings. All piquets have been thinned to one tree per piquet.

As the experiment was originally designed to test the efficiency of the ant *Macromischoides aculeatus* as a capsid control on mature trees, chemical means are employed to ensure that capsid attack is kept at a minimum until the trees have matured. Pending this it has been decided that the plots can be used for other entomological experiments.

During the year two experiments have been laid down on this trial. In the first, alternate plots have been pruned of all leading chupons, in an attempt to reduce capsid damage by promoting the growth of fan branches which appear to be less attractive to capsids. This is a common practice in some South American countries and notably in Costa Rica, where this type of pruning is encouraged to simplify the harvesting of the pods. It will be interesting to see if the West African cacao trees will bear an equivalent crop when treated in this way.

In another row of plots several trials have been laid down to test the effect of various chemical treatments on the ant-mealybug complex.

REGENERATION OF CAPSID POCKETS.

All the coppiced trees in the Capsid Pocket Regeneration trials are in good condition and the seasonal flush has been good. Several trees are bearing pods two and a half years after coppicing. Capsid damage has been very slight and all chupons are treated regularly with D.D.T. emulsion.

FOREST RESERVE CACAO PLOTS.

The two half-acre plots of cacao which were planted in the heart of the Pra-Anum Forest Reserve during August, 1946, were visited in 1948.

Despite a fairly long dry spell just previous to the latter visit, the cacao was generally in excellent condition having made good growth. In both plots there are several patches where growth and establishment have been poor.

No sign of capsid damage was seen in the lower plot but scattered and, in some cases, severe capsid damage was found in the upper plot. Several nymphs of *Distantiella theobroma* were found.

This is the first record of damage by either *D. theobroma* or *S. singularis* in these plots, although in the previous report slight damage by *Helopeltis westwoodii* was recorded.

D.D.T. PAINTING AGAINST CAPSIDS ON YOUNG CACAO.

Control of capsids on the coppiced plots.

Chemical control was continued on those coppiced plots mentioned in last year's report as having been used for testing the comparative effectiveness of different concentrates. Supplies of those concentrates having become exhausted, all the trial plots were treated with the same concentrate (2.5 per cent. D.D.T.) and capsid counts continued. As before the capsids were merely recorded and not removed from the plant.

TABLE 23.
EFFECT OF D.D.T. PAINTING.

Number of Block.	Capsids seen per plot.	
	Control.	Treated.
A 1	40	4
A 2 and 3	365	31
C 1	121	21
C 2 and 3	687	52
C 5	56	15
Average	254	25

The number of chupons varies widely from block to block but the effectiveness of the control is equally well shown if the figures are reduced to the number of capsids seen per 100 chupons.

TABLE 24.
EFFECT OF D.D.T. PAINTING.

	Capsids seen per 100 chupons.
Control Plot (525 chupons) ...	242
Treated Plots (2,713 chupons) ...	18

Large Scale Field Test.

Treatment was continued on one half of the sub-station at Adonkwanta and in February, 1949, when the capsid damage was at its worst, an examination was made of every plant on the farm and the following results were obtained.

TABLE 25.
EFFECT OF D.D.T. PAINTING AT ADONKWANTA.

	Total No. of seedlings.	No. damaged by capsids.	No. damaged by other causes.	Per cent damaged by capsids.	Per cent damaged by other causes.
Treated Section ...	23,388	3	238	0.01	1.02
Untreated Section ...	23,827	6,369	68	26.7	0.3

"Damage by other causes" includes beetle and borer damage and severe defoliation caused by drought.

Since the last Annual Report, the farms on both sides of the road have been divided into blocks, of which there are twenty-one on the untreated side of the road. The scattered nature of the capsid damage is confirmed by the fact that in the most badly damaged block nearly 73 per cent. of the trees were severely damaged and that in nine blocks the damage was over 25 per cent.

There can be no doubt as to the effectiveness of D.D.T. painting when it is properly carried out.

This method of control has now been amply proved and a large number of commercial emulsifiable concentrates were obtained and tested for ease of dilution and lasting properties of the diluted emulsion. Most of the concentrates were easy to dilute but great variation was shown in the length of time before creaming or sedimentation took place. One sample which was easy to dilute was outstandingly good as the diluted emulsion remained dispersed for many days and, although it contained only 20 per cent. D.D.T., this concentrate has for the present been recommended for adoption by the Department of Agriculture.

IV. SOIL SCIENCE.

At the beginning of the year fundamental changes occurred in the Division of Soil Science. The detailed Soil Survey of the Institute's area was successfully accomplished and with the arrival of the new Soil Scientist it was decided to concentrate the interests of the Division on the problems of soil fertility and nutrition of cacao plants. In this connection new experiments have been initiated.

A considerable time has necessarily been spent on preparatory work, initial training of newly appointed assistant staff and adaptation to rather difficult laboratory conditions. In consequence the actual work did not begin until the end of May.

YOUNG CACAO GROWN IN SAND CULTURES IN NUTRIENT SOLUTION.

The general aim of this experiment was: (1) to observe and establish the response of young cacao plants to, and symptoms of, both deficiencies and excesses of major nutrients, (2) to infect all plants with swollen-shoot virus and record the differences, if any, in speed of infection and severity of the disease according to treatment, (3) to carry out chemical tests of leaf tissues and examine the changes of mineral status of both healthy and infected plants caused by under or over-nutrition.

The experiment was laid out in one of the Institute's greenhouses. The technical material used has been such as available locally, i.e., clay pots, soaked in paraffin wax, local sand thoroughly washed and rain water.

The adopted normal nutrient solution contained: 16 m.eq. NO_3^- , 10 m.eq. K^+ , 2 m.eq. H_2PO_4^- , 2 m.eq. NH_4^+ , 6 m.eq. Ca^{++} , 4 m.eq. Mg^{++} , 4 m.eq. SO_4^{--} and appropriate amounts of Fe^{+++} , Mn^{++} , Zn^{++} , Cu^{++} and B per litre.

Two plants were grown in each pot and each pot received one litre of nutrient solution in four daily portions and one thorough washing with pure water per week.

The treatments included: Control, Normal nutrient solution, NP, NK, PK, N_4PK , NP_4K , NPK_4 (i.e., four times more than normal of N, P or K, respectively), N_8PK , NP_8K , NPK_8 , no SO_4^{--} , no Mg^{++} , $\frac{1}{4}$ Mg, $\frac{1}{2}$ Mg and 2 Mg, i.e., $\frac{1}{4}$, $\frac{1}{2}$ and twice the normal amount of Mg.

Cacao beans were planted on the first of June and the application of nutrients began two months later. In the meantime plants were watered daily and grew on the reserves of nutrients contained in the cotyledons.

At the beginning of the fifth month of growth symptoms on leaves and signs of disturbance of growth began to appear; the difference in appearance and health of the plants became more striking with age.

Records of growth were taken for the last time when the plants were eight months old and included: number of leaves (actual), number of leaves dropped, stem thickness, length and width of the three hardened top leaves, height of plant. Out of the figures obtained a "growth index" has been tentatively calculated in an attempt to express in one figure the general condition of the plant. Details will be reported later.

GENERAL OBSERVATIONS (Made when plants were ten months old).

1. Plants grown in normal nutrient solution, *i.e.*, NPK + Ca, Mg and Minor Elements, grew well, showing no abnormal symptoms on leaves and no disturbance of growth.

2. Control plants, grown in water without nutrient solutions, were very stunted, leaves slightly chlorotic and reduced in number, otherwise they looked healthy.

3. Plants grown in solutions deficient in nutrients:—

No P—plants were tall, but thin with small pale-green elongated leaves, otherwise without dangerous symptoms.

No N—growth strongly retarded, leaves pale-green with signs of tip scorch on the oldest ones.

No K—growth slightly retarded, plants looked strong with large dark-green leaves. Necrosis, which, however, proceeded very slowly, appeared around the edges of the older leaves in the sixth month of growth.

4. Plants grown in solutions with excess of nutrients:—

Excess of Nitrogen.—Growth strongly affected, very severe necrosis, around the edges of the leaf, moving between the primary veins towards the midrib, began to appear at a very early stage of growth. These symptoms, very similar to those on "no potassium" plants, but much more strongly developed suggested potassium deficiency induced by excess of nitrogen. This was confirmed by preliminary chemical tests of leaf tissue. Plants receiving eight times more nitrogen than "normal" began to shed leaves early and died out in the eighth month of growth. Their "growth index" was smaller even than that of "control" plants. Plants receiving four times more nitrogen than "normal" still survive (tenth month of growth), but with leaves more or less three quarters necrotic.

Excess of Potassium.—Growth considerably retarded, symptoms in the form of round spots, reddish-brown in colour, began to appear early between the primary veins, growing in number and size. They were soon followed by necrosis of the tip and upper part of the leaf. Plants began to shed their leaves in early stages of growth. Those receiving excess of potassium eight times greater than "normal" died in the eighth month of growth. Those with excess of potassium four times greater than "normal" are about to die.

Excess of Phosphorus.—Plants receiving both four and eight times more phosphatic ion than normal had their growth only very slightly retarded and—apart from certain signs of necrosis on the older bottom leaves at the points where the distal ends of the primary veins approach the edge of the leaf—appeared quite healthy and normal.

Magnesium.—Varying doses of Mg ion in nutrient solution did not seem to affect the growth of plants greatly. With “no Mg” in the nutrient solution plants were slightly smaller and showed, on the oldest bottom leaves, symptoms in the shape of a white-yellowish “oak-leaf” pattern. Otherwise the plants looked healthy and normal.

SO₄-- ion omitted.—Plants grown in solution where SO₄-- ion had been replaced by ce⁻ ion showed no symptoms of any disturbance of growth. They looked even stronger and had a slightly higher “growth index” than those in “normal” NPK solution. At the time of writing symptoms of certain discomfort began to appear on all plants with the exception of “no SO₄--” treatment. That might suggest that either a high concentration of SO₄-- ion may slightly inhibit growth, or (as has been noticed in the field in Trinidad) increased concentration of ce⁻ ion may have a favourable influence.

Preliminary Conclusions.

1. Cacao seems to be a more sturdy plant than is generally supposed, being able to survive for a long time in conditions of very severe deficiencies of nutrients. Control plants—grown in “pure” sand and “pure” rain water—have been able apparently to take advantage of those minute quantities of not easily available foodstuffs (undecomposed minerals and traces of organic matter), which might have been found in their growing medium.

2. Out of three main nutrients the deficiency of phosphorus seems to affect the general growth most, although not the health, of cacao plants. The plants deficient in phosphorus show the smallest “growth index” of all three treatments.

3. Even a great excess of phosphorus, however, does not affect cacao plants to any extent.

4. On the other hand cacao shows striking sensitiveness to excess of N and K.

5. This last observation may have a practical significance. As the soils of tropical forests are probably not deficient in nitrogen and potassium, and may even at times have an excess of those elements in relation to available phosphorus, uncritical application of nitrogenous or potassic fertilizers may seriously affect the growth of young cacao or the yield of bearing cacao.

6. From the above observation it is, however, not clear what exactly causes the harmful effects on the growth and health of cacao.

There are the following possibilities :—(a) accumulation and toxicity of NO_3^- or K^+ ions in plant tissues, (b) deficiencies of other nutrients induced by excess of one of them, or (c) the upsetting of the balance of nutrients.

To answer these questions an extension of the present experiment has been commenced.

Chemical Tests of Leaf Tissues.

These tests have been started, along the general lines adopted in Long Ashton Research Station. Considerable amount of time and effort had to be devoted to the adaptation of methods to laboratory conditions, where the day temperature fluctuates between 79° F. and 93° F. with very high air humidity.

Infection with Swollen-Shoot Virus.

Infection by grafting of one plant in every pot was carried out when the plants were eight months old. Records of the time of appearance of symptoms of the disease and their character are being taken in detail.

Influence of method of application of superphosphate on bearing cacao.

This experiment was commenced in August, before the main harvest began. An unconventional method has been adopted in its layout. The experimental area consists of eleven irregular "patches" scattered in the bush, with—so far as possible—uniform type of soil, cacao trees and environmental conditions.

Each selected "patch" has been divided into three sections :—

- (a) Control.
- (b) Superphosphate broadcast round the trees within a circle 4 to 8 feet from the tree trunk. Yearly rate: two pounds per tree in two applications.
- (c) Superphosphate, weighed in 2 ounce paper bags, has been placed round the tree trunks at a distance of 6 feet and at the depth of 1–6 inches. Four bags in each application four times a year, *i.e.*, 2 lbs. superphosphate per tree per annum.

Sections "broadcast" and "placed" have been surrounded by trenches, 1 foot wide and 2 feet deep subsequently filled in with soil, with the aim of separating the experimental trees from outside root influence.

Before the experiment was started a record of the number of pods was taken from every tree and individual tree yields will be recorded.

N.P.K. Experimental Plots with Young Cacao.

These had been laid out in 1942 and were taken over in 1948 by Soil Science from the Agronomy Division. This experiment is arranged in randomized blocks with eight standard treatments. The sixth and seventh applications of fertilizers were carried out in October and March. Single trees have begun to bear pods, but no noticeable difference in growth of trees has been observed between the treatments. The difference in physical conditions of the soil in the experimental area (part of which had been a village site) seems to have a greater influence on the growth of plants. Records of stem thickness, assumed to be the best characterizing single value, have been taken. The variations in stem thickness within one plot are very great, but the mean values for the whole area reveal certain differences between treatments. They are given below in inches :—

TABLE 26.
STEM DIAMETERS IN INCHES.

Contr.	N	K	P	NK	NP	PK	NPK
1.47	1.35	1.43	1.50	1.37	1.48	1.54	1.47

These crude statistical figures may suggest that application of N, K or NK causes a certain suppression of growth, whereas the presence of P in the treatment counteracts unfavourable influence of K and N or may even promote growth as in the case of the PK treatment. This may confirm to a certain extent the observations made on plants grown in sand cultures.

Soil Moisture Estimations.

Over 1,400 estimations have been carried out on the experimental area during the whole dry season, from the beginning of December until the end of March.

Figures given below are the mean per cent. of soil moisture, at the depth of 6 inches, for Control and N.P.K. treatments.

TABLE 27.
SOIL MOISTURE AT 6" DEPTH.

		Days after rain.						
		1	2	4	7	10	14	21
Control	...	14.7	12.3	11.8	11.8	11.2	9.5	9.1
N.P.K.	...	15.4	13.8	11.3	11.7	11.3	9.9	9.4

Decrease, as might be expected, occurs during the first two to three days after rain; later, however, the decrease becomes very gradual. The content of available moisture has not yet been estimated, therefore wider conclusions cannot be drawn.

Soil fertility tests with maize.

These have been carried out in the N.P.K. experiment described above. Maize was grown in one square yard plots with 3 inch by 4 inch spacing. After three weeks of growth the plants were cut with scissors at ground level and weighed on the spot. Figures given below represent in grammes the mean weight of green matter of 100 maize plants.

TABLE 28.
WEIGHT OF MAIZE GREEN MATTER.

Contr.	N	P	K	NP	NK	PK	NPK
405	402	452	465	488	461	478	460

To draw any far reaching conclusions from this preliminary experiment is precarious. The maize plants were grown under partial and not uniform shade from cacao trees. There may well have been factors influencing growth other than the nutrient status of the soil. Even so, the absence of response to treatment with nitrogen alone and considerable response to the PK and PN treatments may seem to be worth noting.

Soil Surface Protection.

A new experiment on methods of soil surface protection has been designed and the preparatory work for the lay-out is in progress. Cacao will be planted on land cleared of all bush vegetation, with tree cassava as temporary shade and *Gliricidia* as permanent but only partial shade. The experiment will include studies on soil deterioration and changes in its condition, induced by different treatments, as compared with the initial state and with the forest soil untouched by human activities.

V. CHEMISTRY.

LABORATORY ACCOMMODATION.

Although the Institute Cartography room has been converted into a chemical laboratory, accommodation for the Division is still inadequate. The major portion of the Division's laboratory space has been loaned to the Soil Survey Section of the Department of Agriculture.

ESTIMATION OF BUTTER-FAT AND ALKALOIDS.

In the general survey of the Trinidad Introductions, Progeny Trials and Seasonal Variation experiments, the butter-fat estimations have been extended to include determinations of caffeine and theobromine. Slight modifications in the procedure for estimation of butter-fat in cacao kernels, previously described in the 1947-48 W.A.C.R.I. Annual Report, have been made during the year and the method as extended to include the cacao alkaloids may here be given for the sake of completeness.

Procedure.

All cacao beans used in the estimations were freshly harvested, mucilage and testas were removed and the beans dried at 105° C. for 24 hours.

The dried beans were minced, pounded in a mortar and then warmed to 40° C. in an electric oven until the bean mass could be beaten into a smooth paste. Duplicate 5.0 grm. portions of the paste were weighed accurately and extracted for 20 hours in a Soxhlet apparatus using light petroleum (bp. 50-60° C.) as solvent. The solvent was then distilled and the residue dried to constant weight at 105° C. in an electric oven (A).

The residual cacao powder was mixed with half its weight of freshly-calcined MgO and 10 cc. distilled water added slowly from a burette until all the particles were wetted. The mixture was heated in a porcelain basin on a hot plate and partially dried, a process which took 30 minutes. It was repowdered, wrapped in a fat-free filter paper and extracted for 20 hours with chloroform. After distillation of the chloroform the residue, which contained fatty material plus alkaloids, was dried at 105° C. and weighed (B). The fat was removed by allowing the mixture to stand overnight in 100 cc. light petroleum (bp. 50-60° C.), filtering through a tared Gooch crucible, drying the precipitate at 105° C. and reweighing (C).

The dried solid (C) was then treated with 100 cc. benzene in order to remove caffeine and the solid residue, consisting of theobromine, was filtered through a second tared Gooch crucible.

All determinations were carried out in duplicate and results were expressed as percentages of the various constituents in the oven-dry nib.

$$A + (B - C) = \text{Total butter-fat content.}$$

$$C = \text{Total alkaloids.}$$

$$D = \text{Weight of theobromine.}$$

$$C - D = \text{Weight of caffeine.}$$

Of the 29 selections examined from the Trinidad Introductions plot, highest butter-fat yields were obtained from Criollo and Upper Amazon material as indicated below :—

TABLE 29.
CACAO BUTTER-FAT CONTENT.

Stand No.	Progeny No.	Selection.	% Cacao Butter.		
			Light Petroleum Extract.	Chloroform Extract.	Total.
794	T 92	Upper Amazon (Crossed) =Nanay	56.84	0.92	57.76
910	T 82	Upper Amazon (Crossed) =Nanay x Parinari ...	51.52	5.78	57.30
954	T 86	Upper Amazon (Crossed) =Parinari	54.76	2.50	57.26
1298	T 48	Criollo (Illegitimate) =Nicaraguan... ..	54.58	2.54	57.12
1144	T 55	Upper Amazon (Illegitimate) =Morona	52.52	4.60	57.12
823	T 63	Upper Amazon (Crossed) =Nanay x Parinari ...	54.78	2.16	56.94

Note :—In the above selections Illegitimate progenies (not from controlled pollination) are given where no legitimate progeny of the particular type is available.

Harvesting of material for the First and Second Progeny Trial experiments, Seasonal Variation in the Institute crop and Variation inside the high-yielding strains E1 and N38, continued throughout the year and will require some time yet for completion. (For full details of the harvesting procedure in each experiment see W.A.C.R.I. Quarterly Report (October–December, 1948).)

Tannin Distribution.

Preliminary experiments have been started prior to a large-scale investigation into the tannin distribution in *Th. cacao* seedlings. As material will be harvested much quicker than it can be analysed, standard storage conditions are being established and a suitable experimental procedure developed in order to eliminate the effect of substances such as chlorophyll which may be extracted along with the tannins.

Soluble Tannins.

Experiments on the soluble tannin content of West African Amelonado cacao kernels have indicated the presence of more than 20 per cent., the amount decreasing rapidly with increase in time

between harvesting pods and performing analyses. Comparisons with selections from other Forastero and white bean Criollo cacao await the 1949 mid-crop harvest.

Small-scale Fermentations.

Experiments have been in progress throughout part of the year in an effort to develop a method for the fermentation of the contents of a single pod or at most two pods. It was found necessary :—

- (a) To use pulp from a large-scale fermentation to act as a "starter" in the "single-pod" experiments.
- (b) To aerate the bean mass.
- (c) To establish and maintain suitable temperature conditions artificially.

Percentage fermentation has been determined on the appearance of beans in longitudinal section after sun-drying and the following arbitrary criteria of fermentation have been employed :—

Fermented beans :

- (i) Shells brittle and easily removable from the kernels.
- (ii) Colour—deep chocolate brown.
- (iii) Cotyledons opened and easily shattered into nibs.

Slightly Underfermented :

- (i) Shells brittle and not so easily removable as in (i).
- (ii) Colour—deep chocolate brown to light brown.
- (iii) Cotyledons partially opened or unopened.

Underfermented :

- (i) Shells removable with difficulty from cotyledons.
- (ii) Colour—purple or purple-brown.
- (iii) Cotyledons unopened.

Best results to date (46 per cent. fermented; 54 per cent. slightly underfermented) were obtained when the following conditions were satisfied :—

1. 10 cc. pulp from a large-scale fermentation which had been in progress for 30 hours, were mixed with 2.0 gm. dextrose and the sweetened pulp added to the bean mass.
2. Initial incubator temperature = 43° C. and the temperature of the bean mass was controlled between 43° C. – 49° C. during the six days fermentation.
3. Bean mass was turned once in 24 hours but continually aerated throughout the fermentation at a rate of 3 litres/24 hours.

In the slightly underfermented beans, the colour was satisfactory but the cotyledons remained unopened.

Investigations are continuing.

VI. BOTANICAL AND HORTICULTURAL STUDIES.

PROPAGATION OF CACAO BY CUTTINGS.

Propagation in Bins.

Rooting.

Owing to a shortage of suitable semi-hardwood material, soft-wood cuttings with green terminal leaves were used for propagation. These cuttings retained their freshness throughout propagation and showed no leaf-drop; root development was slower than on ripewood cuttings, but soft-wood shoots cut at the thickened base of the new flush gave average rooting percentage of 83.6 as against 62.8 per cent. for ripewood cuttings.

At a time when optimum growth conditions prevailed, good semi-hardwood cuttings rooted better than soft-wooded ones. Rooting figures obtained from ten replications of mixed clones were as follows:—

Semi-hardwood cuttings ...	...	43.3	per cent.
Soft-wood cuttings ...	...	40.8	„ „
Union cuttings ...	...	46.4	„ „

Hardening of rooted cuttings.

The use of glass covered hardeners has been adopted since it has proved successful both in the dry and wet seasons of the year. High hardening percentages have been maintained during the year.

The rooting of cacao cuttings is preceded by a callusing of the cut end. An experiment was conducted to test the ability of callused but unrooted cuttings to form roots after transference from the propagators to the hardening bins. Eighteen cuttings which had callused but not rooted were potted and placed in the hardeners beside 47 rooted cuttings. At the end of the normal hardening period of three weeks only one of the callused cuttings was properly rooted and hardened; another had shed all old leaves but had produced a fresh growth flush with small leaves. With the remainder all leaves had been dropped, but the growing points were still fresh and active; six of this number had formed roots 2–10 inches long. Of the 47 initially rooted cuttings which constituted the control, 44 hardened successfully.

Open-air Propagation.

An attempt was made to root cacao in an outdoor bed along lines similar to those used in Costa Rica and Surinam. (Cacao Information Bulletin, Inter American Institute of Agricultural Science; Vol. 1, No. 5, March, 1948.) Running water was not available to provide a continuous mist-spray, but spraying with a rosed can was carried out at hourly intervals. Partial shade was provided by bamboos. Within 36 hours of planting the cuttings showed signs of wilting and leaf drop followed. Defoliation of all but two out of

the 20 planted had occurred by the fifteenth day; after 30 days the two survivors were also defoliated but had each produced a single root half an inch in length.

PROPAGATION OF OTHER SPECIES OF *Theobroma*.

By budding.

Budding *T. speciosum* and *T. microcarpum* were attempted. No "takes" of either species on *T. cacao* were recorded but buds of *T. speciosum* formed tissue unions on *T. bicolor* stocks and several successful budgrafts have been made between these species.

By cuttings.

Material from *T. microcarpum* consisted of newly ripened flush and from *T. speciosum* of well ripened wood. Ten cuttings were taken from each species and treated with B-Indolyl butyric acid before planting. Two of the former species and three of the latter rooted after two and five months respectively, and a further three of the latter had rooted sufficiently well for potting after six months.

PROGENY TRIALS.

First progeny trial (planted 1940).

An analysis of the 1945-48 yields in the 1st Progeny Trial brings out the interesting fact that the superiority of the E.1 progeny lies mainly in performance on the "bad" plots (due to poor soil and capsid damage). In the whole trial, the E.1 progeny has produced 605 lbs. of wet cacao, and the next best progeny, P4/9 has yielded 405 lbs. If only the best 16 plots are considered, however, there is little difference between these two progenies—388 lbs. from E.1 and 373 from P4/9. The E.1 progeny has outyielded that of P4/9 because more seedlings have come into bearing and also because E.1 has a higher pod value (4.2 ozs. wet beans per pod compared with 3.6 ozs. for P4/9).

Second progeny trial (planted 1942).

In this trial E.1 progeny is again the best; and as in the 1st Progeny Trial more E.1 seedlings have come into bearing than have seedlings of any other progeny. A close rival to E.1 is a Tafo selection, TF2, which has an even larger pod (4.9 ozs. wet beans per pod).

NEW INTRODUCTIONS.

Certain types of cacao of Upper Amazon origin are now outstanding in vigour and early-bearing. In the Introductions plot there are 1,936 trees, planted as basket seedlings in 1945. In the 1948 maincrop 3,141 pods were harvested from the plot, but of this total, 1,062 pods were borne by only 115 trees—all progeny by cross-pollination of three Upper Amazon trees. Thus five per cent. of the trees on the plot yielded 33 per cent. of the crop. The best progeny yielded in 1948, at four years old, an average of 13.5 pods per tree.

The only type not of Upper Amazon origin which can be compared with those for yield and vigour is the second generation progeny of the Costa Rica clone 613. These seedlings yielded an average of 4.1 pods per tree. The progeny of I.C.S.70, with 2.8 pods per tree is the best of the Trinidad types. West African Amelonado yielded only 11 pods from 266 trees.

An analysis of stem-diameter measurements has shown that visible differences in vigour are highly significant. The mean stem-diameter at six inches above ground level for each type is:—

Upper Amazon	...	...	6.44 ± 0.146	centimetres.
Ecuador	...	...	5.07 ± 0.344	,,
Criollo	...	...	4.72 ± 0.279	,,
Trinitario	...	...	4.66 ± 0.249	,,
W.A. Amelonado	...	...	3.90 ± 0.152	,,

The Upper Amazon types are significantly more vigorous and W.A. Amelonado less vigorous than the other types.

INTERSPECIFIC POLLINATION.

When flowers of *T. cacao* are pollinated with *Herrania* spp. pollen, the resulting embryos are malformed and none has proved viable even when cultured in nutrient solution or agar.

Herrania spp. flowers presumably pollinated with pollen of *T. cacao* have produced *Herrania*-like beans which are germinating well.

NATURAL POLLINATION.

During the 1948 crop, the amount of natural cross-pollination between cacao trees has been estimated on two plots. On the old station, a tree which produces albino seedlings when self-pollinated yielded 56 pods, of which 12 (23.7 per cent.) were cross-pollinated. The genetical segregation of the albino factor in the selfed pods showed it to be due to a single recessive gene. There were 1,093 normal seedlings to 358 albinos—a 3:1 ratio.

On the Square Mile, five green-podded trees, each surrounded by red-podded trees, yielded a total of 76 pods. The presence of red pigment (axil spot) in the seedlings revealed that 14 (18.4 per cent.) of these were cross-pollinated with pollen from the red-podded trees.

VII. MYCOLOGY.

Mycological work has been directed mainly towards pod diseases.

POD DISEASE CONTROL.

An experiment was set up prior to the 1948 main crop season to investigate the effect of fungicide and insecticide spraying on damage

to pods. The Division of Entomology is responsible for carrying out the spraying.

There are five treatments and 10 replications. Each plot consists of 10 mature, bearing trees. The treatments are as follows :—

1. Spraying with Bordeaux mixture.
2. Spraying with Perenox.
3. Spraying with nicotine sulphate.
4. Weekly harvesting.
5. Control.

The spraying is at weekly intervals. All treatments have been harvested every three weeks, except the weekly harvested plots. The spray is directed only at the pods, but much inevitably falls elsewhere.

The records for the first seven harvests (21 weeks), covering almost the entire 1948 main crop, have been analysed. They show that no treatment has significantly affected the ratio of number of pods per pound of wet beans, the important criterion. Disease incidence was, however, reduced by certain treatments. For example, the percentage of pods infected with *Phytophthora palmivora* ("black pod") was lower in the Bordeaux mixture—and Perenox-sprayed plots and the weekly harvested plots than in the control plots and those sprayed with nicotine sulphate, the difference being significant. The percentage of black pod infections in the Bordeaux mixture-sprayed plots was 4.5, compared with 12.5 per cent. for the control plots.

Some significant differences were evident with regard to "brown pod" (*Botryodiplodia theobromae*) infection, Perenox spraying being the best treatment. Spraying with Bordeaux mixture appeared to give control of *Helopeltis* damage. The percentage of pods damaged by *Helopeltis* in the Bordeaux mixture-sprayed plots (19 per cent.) was significantly lower than in any other series. Nicotine sulphate spraying gave 35 per cent. of pods damaged, significantly lower than 55 per cent. for the weekly harvested plots. The figure for the control plots was 41 per cent.

Although no increases in bean yields have been obtained, the results so far obtained are encouraging in that it has been possible to reduce infection. It was considered likely that differences in bean yields (in relation to numbers of pods) might show if the harvesting were carried out at longer intervals, to approximate more closely to normal peasant practice in West Africa. (A "damaged" pod may well give a full yield of good beans; if the husk remains unbroken, the pod disease fungi take a considerable time to progress into the interior and spoil the beans. The beans are likely to become affected when a disease pod remains on the tree for a long time). Accordingly, the experiment was modified during February, when very few pods were on the trees, and harvesting is now being carried out at six-weekly intervals.

It is worthy of mention that in Costa Rica it has been found highly profitable to spray into the canopy of cacao trees, to reduce the reservoirs of *Phytophthora palmivora* infection present there. Conditions in the Gold Coast appear to be different, in that the major damage caused by *P. palmivora* is to the pods, and the main reservoir of infection consists of cushion infections and cankers, which are by no means amenable to direct fungicidal treatment. Chupon wilt attributable to *P. palmivora* does not appear to occur here. It should also be noted that the average rainfall in Costa Rica is much higher than that in the Gold Coast, and also more evenly distributed, factors which greatly favour the development and spread of black pod disease.

FUNDAMENTAL STUDIES ON POD DISEASES.

Several lines of fundamental work on black pod, mealy pod and warty pod diseases have been commenced, including the observation of sporangial and conidial germination, and artificial infection experiments.

It has proved easy, in the laboratory, to infect pods with *Phytophthora palmivora*, by means of a sporangial suspension, through wounds, but infection is not always obtained in the absence of wounding. In hanging drops of water, at day room temperatures, the sporangia germinate mainly by the formation of germ tubes. Zoospore production has been observed rarely.

WARTY POD DISEASE.

It has already been shown that this disease appears to be caused by the fungus *Botrydiplodia theobromae*. No progress has yet been made towards a further understanding of the etiology. The disease was more common at Tafo in 1948 than in 1947. On 12 quarter-acre observation plots the proportion of trees bearing warty pods, as a percentage of the total number of bearing trees, varied from 28 per cent. to 81 per cent., with a mean of 61 per cent. These figures contrast with a range of five per cent. to 73 per cent. and a mean of 38 per cent. for the 1947 main crop season.

Other data showing that warty pod disease was more prevalent in 1948 than in 1947 were obtained from records of the Agronomy Division, which show that warty pods formed 7.7 per cent. of the 1948 old station main crop, compared with 3.5 per cent. in 1947. In 1948, 18.7 per cent. of warty pods were discarded, compared with 5.3 per cent. discarded from the total crop.

CALONECTRIA RIGIDIUSCULA.

This fungus has been found to occur fairly frequently on rotting cacao pods still on the tree. On this substratum spores (macroconidia) are formed in abundance, and it may be that rotting pods form a considerable reservoir of infection for capsid lesions. Fructifications on cacao wood are uncommon.

C. rigidiuscula was isolated from infected capsid lesions on cacao shoots collected in Sierra Leone.

Some new inoculation experiments with *C. rigidiuscula* have been set up but no results are yet available.

VIII. SUB-STATIONS.

Growth of the cacao on all sub-stations was encouraging during the early part of the year, but with the advent of the dry season, seedlings growing under borderline conditions in the drier areas suffered severe defoliation and heavy losses were incurred.

The provision of adequate shade on land previously depleted of plant foods, has led to almost complete suppression of grass and undesirable pioneer weeds and to a consequent improvement in the growth of the cacao.

Many of the young trees at Nankese, Adonkwanta and Kukua flowered in May and June, 1948, when three years old, and a small number of pods matured.

Swollen-shoot infection has not been heavy and has continued to be associated with infected mature trees on contiguous native farms.

Routine painting with D.D.T. emulsion and the removal of swollen-shoot diseased plants were continued on all cacao except the control areas of Adonkwanta and Kukua.

AKWADUM.

The *Cassia siamiae* hedges which formed the original guard rows of the Hedge Trial Area have been removed. A further reduction of the stand of *Leucaena glauca* trees in the regularly spaced cacao plots was effected, and tree cassava was planted in lightly shaded areas.

Seventeen diseased trees, the majority within a few yards of the perimeter, were removed during the year.

Control of capsids by painting with D.D.T. emulsion has been effective, but many of the trees are now too high for hand painting.

Drought caused defoliation in August and again in December-January, but the trees made an excellent recovery.

NANKESE.

Particular attention has been paid to the provision of shade in the areas where the cacao seedlings, either due to previous farming or to inherently poor soil, have not thrived.

The drought in December and January was particularly severe and a large number of seedlings either succumbed completely, or were

killed back almost to ground-level. Even on the better areas the tips of the fan branches on some of the more forward seedlings were completely desiccated.

Only one swollen-shoot infected seedling was found and this was 60 feet from the boundary.

Damage by Scolytid beetle borers was more severe than usual.

KUKUA.

The drought effect was again severe on the higher parts of the farm and considerable losses of seedlings resulted. Trees in the valleys suffered defoliation but have recovered and are flowering heavily.

The capsid population remained at a low level and little damage was seen on either the treated or control areas.

Thirty seedlings, suffering from swollen-shoot were recorded, 20 in Plot A (Control) and 10 in Plots B and C (treated). All infected seedlings were near the boundary, or in Plot A, associated with previously recorded diseased seedlings which had been left for observation.

ADONKWANTA.

Routine weeding and shade control continued throughout the year and the condition of the farm is highly satisfactory. The drought was less severe than at other sub-stations and the majority of the seedlings received no set-back.

There is a spectacular difference between the D.D.T. painted plot and the control; advantage of this has been taken by including this sub-station in the demonstration given to farmers by the Department of Agriculture.

Eighteen seedlings infected with swollen-shoot disease were recorded during the year. Eleven of these were in the treated plot and were removed and seven in the control plot were left for observation. All the latter were near 82 mature diseased trees on the farm boundary. The owner has agreed to the removal of this source of infection.

KORANSANG.

Growth of seedlings, except on the rocky upland, was excellent and the drought effect was not so severe as in the neighbouring Kukua farm.

Losses from swollen-shoot disease were surprisingly low in the seedling population, only 20 infected plants being recorded as against 293 mature and four coppiced trees carrying the symptoms.

In addition 23 mature and 61 coppiced trees died from causes other than swollen-shoot disease.

Damage by capsids was negligible.

Many of the trees coppiced in 1945 are carrying quantities of flowers and cherelles.

IX. AGRONOMY—TAFO STATION.

CACAO CROP.

Old Station.

Minor and major crops merged completely, there being continuous harvesting from early August to the end of January.

The average interval between picking was reduced from that of previous years, and this, coupled with the monthly removal of all pods in the off season, had a marked effect in minimizing the loss of pods from disease. The percentage of pods discarded fell from 16.4 in the 1947-48 season to 5.5 in the present crop. No doubt the low rainfall for July, August and September was also a major factor in reducing pod diseases.

All cacao sold was classified as 1st grade, weather conditions for curing and drying being very favourable.

Yield per acre from the recorded plots rose from 399.9 lbs. of dry cacao in 1947-48 to 656.4 lbs. in 1948-49. The following table gives crop data for 63.69 acres of recorded cacao for the years 1938-49.

TABLE 30.
MINOR-MAJOR CROP YIELDS, 1939-1948.

Season.	Number of pods harvested.	Per cent. of pods discarded.	Wet weight of beans in lbs.	Per cent. dry weight to wet weight	Yield per acre dry cacao in lbs.
1938-39...	775,065	15.8	127,467.7	43.8	807.7
1939-40...	716,487	11.7	132,627.3	40.8	782.8
1940-41...	706,443	8.4	140,161.3	41.4	787.6
1941-42...	767,461	13.3	139,888.8	40.0	794.9
1942-43...	621,724	10.5	115,388.4	43.1	748.9
1943-44...	643,180	16.4	113,995.2	40.4	720.0
1944-45...	593,217	14.7	108,037.3	40.8	688.7
1945-46...	547,762	29.2	76,657.7	40.9	492.0
1946-47...	368,859	5.5	58,563.9	44.5	409.3
1947-48...	355,480	16.4	63,507.2	40.1	399.9
1948-49...	488,313	5.5	98,710.1	42.4	656.4
11-Year Mean ...	598,545	13.5	106,822.3	41.6	622.6

Delivery of crop from 57.94 acres of cacao which have been recorded without break since 1938 are given in Table 31.

TABLE 31.

DELIVERY OF CROP.

(224 $\frac{1}{4}$ ACRE PLOTS PLUS 31 $\frac{1}{16}$ ACRE PLOTS) 57.94 ACRES.

Crop.	Date of picking.	Number of pods harvested.	Per cent. discarded.	Wet weight of beans (lbs.)	Per cent. dry to wet.	Average Yield per acre dry (lbs.)
MINOR	Aug. 4-16 ...	15,012	9.3	3,511.2	35.51	21.5
	Aug. 18-30 ...	37,494	3.7	9,167.9	39.46	62.4
TOTAL MINOR	August ...	52,506	5.3	12,679.1	38.36	83.9
MAJOR	Aug. 31-					
	Sept. 10 ...	48,346	2.4	11,531.1	40.56	80.7
	Sept. 20-Oct. 4	115,896	2.7	25,045.3	42.32	182.9
	Oct. 14-Nov. 4	133,080	4.5	24,888.3	44.56	191.4
	Nov. 9-19 ...	48,801	10.7	8,317.4	43.57	62.5
	Nov. 30-Dec. 9	29,100	10.3	5,073.2	42.30	37.0
	Dec. 15-22 ...	15,425	8.5	2,527.9	45.30	19.8
	Dec. 23-Jan. 3	6,442	13.1	1,030.1	42.59	7.6
	Jan. 7-18 ...	3,946	15.3	628.0	41.72	4.5
	Jan. 22-28 ...	1,474	13.9	229.1	40.82	1.6
TOTAL MAJOR	Sept.-Jan. ...	402,510	5.3	79,270.4	42.99	588.2
TOTAL CROP ...	Aug.-Jan. ...	455,016	5.3	91,949.5	42.35	672.1

Distribution of Plot Yields on the 224 $\frac{1}{4}$ acre plots show a rise in the modal class from 201-400 lbs. to 601-800 lbs.

It will be noted that 56.69 per cent. of the plots yielded over 600 lbs. per acre, the figure which is regarded by farmers as a high yield for healthy mature cacao farms.

TABLE 32.
DISTRIBUTION OF PLOT YIELDS ON
224 ONE-QUARTER ACRE PLOTS IN LBS. PER ACRE.

Yield Class.	Percentage of total number of plots in each class.				
	1944-45	1945-46	1946-47	1947-48	1948-49
0- 200	5.8	8.5	16.5	13.4	5.36
201- 400	9.3	25.3	34.8	38.0	13.84
401- 600	23.1	35.1	26.8	36.2	24.11
601- 800	22.7	19.1	15.6	8.9	24.55
801-1000	24.4	8.0	4.9	3.1	18.30
1001-1200	7.4	3.6	0.9	0.4	8.93
1201-1400	4.9	0.4	—	—	4.46
1401-1600	4.8	—	0.5	—	0.45
1601-1800	0.9	—	—	—	—
Highest plot yield in lbs. per acre ...	1,661.52	1,251.60	1,527.60	1,002.68	1,485.60
Lowest plot yield in lbs. per acre ...	80.12	2.92	Nil	Nil	3.68

Tree Mortality.

A total of 854 trees were lost from the recorded area of the Old Station of which 495 were suffering from swollen-shoot, 24 were suspects and 336 died from undiagnosed causes.

Five swollen-shoot infected seedlings from an estimated population of 90,000 were found and removed.

NEW ACQUISITION.

Harvesting was more frequent than in the previous season and the percentage of pod discards fell from 15.6 to 5.09. Although there was a reduction in acreage, the overall yield of dry cacao increased by five tons. Building operations, clearing for new experiments and swollen-shoot control measures have reduced the area of cacao in the New Acquisition from 259 to 226 acres.

TABLE 33.
YIELD FROM CACAO ON NEW ACQUISITION.

Season.	Pods harvested.	Per cent. pods discarded.	Dry weight in lbs.	Pods per lb. dry cacao.	Yield per acre lb. dry.
1947-48	695,413	15.60	54,430	10.7	210
1948-49	715,642	5.09	65,920	10.3	290

FIELD EXPERIMENTS.

Work on experimental areas on both the Old Station and the New Acquisition continued to be directed towards the formation and maintenance of suitable shade for the cacao.

Forest tree seedlings planted throughout the Uniformity Trial Area of the Old Station included the following species: *Erythrina senegalensis* D.C.; *Bosquiea angolensis* Ficalho; *Antiaris africana* Engl.; *Albizzia ferruginea* Benth.; *Blighia sapida* Koeig.; *Chlorophora excelsa* Benth and Hook; *Enthandophragma* spp.

In the new experimental areas regenerated forest tree seedling growth was encouraged and many seedlings of the quicker growing species are now up to 10 feet high after two years growth.

Among the commoner species are *Terminalia superba*. Engl. and Diels; *Chlorophora excelsa* Benth. and Hook; *Ficus capensis* Thumb and *Ficus asperifolia* Mig.

The original nurse shade comprising tree cassava and banana has been drastically thinned by the removal of alternate banana stands and severe pruning of the tree cassava.

Certain experiments are reported below :—

OLD STATION.

First Progeny Trial Area.

The establishment trial which was run in conjunction with the comparison of progenies has given valuable visual results. The initial temporary shade treatments laid down in 1939 were modified from time to time to meet the requirements of the cacao seedlings; many of the plots have been abandoned due to the poor growth of the cacao, and statistical analysis of yields has therefore been considered impracticable. Of the treatments employed, that using the indigenous "bush" as shade fortified by permanent overhead shade trees has given outstanding results judged on observation, and both the number of trees in bearing and the yield of pods per tree are notably larger than in other treatments.

In the treatment using Plantains alone as shade, 10 plots out of the original 16 have been abandoned, the cacao having failed completely.

NEW ACQUISITION.

Uniformity Trial.

Growth has been good and intensive shading has smothered much of the grass and weeds on the areas previously farmed for food. These areas had been mapped prior to planting and growth rate measurements on the young cacao plants 20 months after planting showed an average repression of growth of six inches in the areas previously covered with grass.

Establishment Trial.

The treatments in this Trial are recapitulated for the sake of clarity.

Group I.—Type of Planting Material.

Treatment A.—Seed at stake dibbled in 3 per piquet.

„ B.—Bare root nursery seedlings.

„ C.—Basket seedlings, minimum root disturbance.

Group II.—Method of Planting.

Treatment D.—As Treatment A.

„ E.—As Treatment A but in 2 feet cube holes filled with surface soil.

„ F.—As Treatment A but soil disturbance as in Treatment B.

Group III.—Efficacy of Mulching.

Treatment G.—Mulching with material from plot.

„ H.—Mulching with double amount of material in G.

„ I.—No mulch.

The last three treatments had seed sown at stake as in A. All plots in Treatment A to F were mulched. The percentage replacement in the second year of establishment is shown below :—

TABLE 34.
PERCENTAGE REPLACEMENT.

Treatment.	Number replacement.	Percentage of total seedlings in treatment.
A	14	0.93
B	4	0.80
C	—	—
D	24	1.60
E	59	3.90
F	6	0.40
G	44	2.90
H	3	0.20
I	40	2.60

Data of growth, expressed as height in inches, were examined statistically.

Standard error for treatment totals at $P = .005 = 10.23$.

TABLE 35.
TREATMENT TOTALS IN ORDER OF MAGNITUDE.

Treatment.	Treatment Total.	Difference.
I	181.1	—
D	195.5	15.4
E	199.7	3.2
G	199.8	0.1
F	201.7	1.9
A	205.6	3.9
H	212.2	} 6.6
B	212.2	
C	301.0	88.8

Treatment C (Basket seedlings) is significantly better than all other treatments. Treatments C, B, H, A, and F are significantly better than treatment I (no mulch).

It should be borne in mind that the plants in treatments B and C are seven months older than those in the other seven treatments. The superiority of Treatment C over B is most marked, particularly if the high rate of replacements in B is taken into consideration (115 per cent. in 1948-49). The poorer development in Treatment I reflects the relatively smaller soil moisture conservation in the dry season.

As a further measure of comparison between treatments, a count was taken of all seedlings which had reached the "jorquette" stage. The figures represent percentages converted to degrees from Fishers Table of Angular Transformation.

Standard error for Treatment Totals where $P=0.05=76.65$.

TABLE 36.
TREATMENT ARRANGED IN ORDER OF MAGNITUDE.

Treatment.	Treatment Total.	Difference.
I	155.3	—
E	130.2	14.9
G	140.4	10.2
D	151.0	11.7
F	155.8	3.7
H	159.2	3.4
A	167.2	8.0
B	209.4	42.2
C	328.1	118.7

Treatment C again emerges as significantly better than all other treatments, whilst Treatment B is significantly better than Treatment

I and E. Although Treatment B is not significantly better than the treatment using seed at stake, there is a strong indication that age of plant is the governing factor for the observations made, and the "jorquetting" might well be used as a measure of maturity.

Spacing Trial.

The general health of the seedlings has been good. This area is particularly subject to tornado damage and it has been found necessary to keep the tree cassava at a much lower level than in other experiments. During the dry season a marked border effect was noticed due to the competition between the bananas forming the plot surrounds and the cacao seedlings. The banana stands were thinned by removing alternate stools and replacing with *Gliricidia*. Losses of seedlings were fairly uniform in all treatments and average 7.5 per cent. of all seedlings at three seedlings per piquet. All piquets were thinned to one seedling after the early February rains.

Thinning Trial.

This experiment was laid down during the year.

Object.

To determine whether it is better to plant cacao closely and later to thin to a density accepted for mature cacao or to plant at the accepted density.

Lay-out.

Three treatments replicated six times, randomised within the blocks. Uniform shade provided by tree cassava throughout.

Treatments.

- (a) Cacao sown at stake, planting distance 8 feet by 8 feet, three seeds per piquet, thinned to one at end of the second dry season.
- (b) Cacao sown at stake, planting distance 2 feet by 2 feet, three seeds per piquet thinned to one at end of the second dry season again thinned by removing alternate rows and alternate plants in the remaining rows after the third dry season and similarly after the fourth dry season giving a final stand of 8 feet by 8 feet.
- (c) Cacao sown as in (b), but thinned by eye to maintain a full canopy and a final stand of 8 feet by 8 feet (farmer's method).

Growth has been good on all plots, although the growth on the closely spaced plots appears to be better, probably due to the greater aggregate amount of vegetation.

Clonal Multiplication Plot.

Six acres of land were planted with cacao seed at stake for eventual use as stocks for the multiplication of clonal material by budding. It was necessary to drain a swampy area in the middle of

the block and the seedlings have been successfully established throughout. Planting distance is 5 feet by 5 feet at three seeds per piquet. *Erythrina senegalensis* D.C. seedlings planted at 28 feet by 28 feet through the block have grown well.

Other New Plantings.

- (a) 1.1 acres of *Herrania* species were planted for seed multiplication.
- (b) 2 acres of West African Amelonado were planted as a future source of experimental material.
- (c) 5 acres of land were cleared for a Spacing Trial of Upper Amazon Types of Cacao.
- (d) Work was started on preparing the land for a Cultivation Experiment (1.9 acres), a second Establishment Experiment (2.7 acres) and five acres of Amelonado to provide future experimental material for the Entomology Division.

TAFO STATION, MAINTENANCE AND GENERAL.

Cacao.

All young seedlings were painted at regular intervals with D.D.T. emulsion as a protection against capsids, as were the selected basal "chupons" on the mature trees.

All loranthus and dead branches were removed in routine pruning operations.

The monthly removal of all ripe and diseased pods has been adopted as standard practice to lessen the chance of pod disease being carried over from season to season.

General.

All roads, ditches, compounds and hedges were maintained in good condition and buildings were kept in a good state of repair.

Three crops of maize were raised on the Dam Site (7½ acres) with the object of exhausting the soil as much as possible prior to flooding.

Yams, maize, and soya beans were grown on land unsuited to cacao.

The vegetable garden produced 4,900 lbs. of vegetables and the nurseries met all demands for ornamental and economic plants.

Routine anti-malarial measures continued and were extended to the W.A.C.R.I. Village.

Timber purchases during the year amounted to 17,332 cubic feet, almost identical with those of the previous year, but it is of interest to note that the cost was £4,577, an increase of 20 per cent.

APPENDIX I.
METEOROLOGICAL DATA.
TAFO STATION.

FIGURES FOR 1948 COMPARED WITH 11-YEAR MEAN.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Highest Shade Maximum 11-year mean Do. 1948 ...	91.1 94	93.3 94	93.4 93	93.0 92	91.9 91	89.1 89	86.6 87	86.2 87	87.9 89	89.7 91	90.3 90	90.4 92
Lowest Shade Minimum 11-year mean Do. 1948 ...	58.7 53	61.8 64	65.8 64	65.8 63	66.6 67	66.7 67	66.5 67	65.2 65	67.2 68	66.7 67	64.9 65	61.9 64
Mean Relative Humidity 11-year mean (9 a.m. G.M.T.)	85.6	83.8	81.3	81.0	81.6	84.5	85.6	85.7	84.4	82.6	81.2	83.6
Mean Relative Humidity 1948 ...	85.7	85.7	83.8	83.2	83.7	87.4	87.5	86.6	87.4	82.1	84.2	87.8
Mean Relative Humidity 11-year mean (3 p.m. G.M.T.)	52.2	50.1	52.2	55.6	60.4	66.0	66.8	65.3	70.3	69.2	64.9	61.1
Mean Relative Humidity 1948 ...	47.8	53.1	54.3	62.1	71.2	76.4	76.0	72.9	72.9	67.7	64.3	61.4
Rainfall in inches. Do. 11-year mean 1948 ...	1.30 0.03	3.53 5.12	5.63 7.67	6.01 5.54	7.34 8.76	8.54 16.43	4.80 3.37	2.86 1.50	5.69 2.95	8.22 6.11	5.63 6.84	2.43 2.67
Number of wet days, Do. 11-year mean 1948 ...	3.7 1	7.6 9	11.7 10	11.0 9	13.6 15	18.5 19	12.8 14	13.3 12	17.4 19	17.5 17	11.5 13	6.7 4

ANNUAL RAINFALL FIGURES: 1938-48.

	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	11-year mean.
Inches 55.33	Inches 84.96	Inches 56.92	Inches 56.59	Inches 59.45	Inches 69.09	Inches 49.12	Inches 68.87	Inches 47.03	Inches 67.30	Inches 66.99	Inches 61.98	

SUB-STATIONS AND TAFO.
MONTHLY RAINFALL IN INCHES—1948.

Station.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
Akwadum	0.04	5.88	4.97	3.45	6.39	11.29	1.93	1.44	2.46	10.47	4.33	0.04	52.69
Nankese	0.05	5.38	2.43	2.51	4.58	8.34	0.97	0.41	1.95	6.98	2.82	0.11	36.53
Koransang	—	0.81	8.74	6.63	5.56	7.54	0.84	0.96	2.48	9.16	3.08	0.40	46.20
Kukua	—	0.73	9.12	5.82	6.79	9.08	0.24	1.58	3.68	8.84	3.31	—	49.19
Adonkwanta	—	7.64	7.41	3.27	7.33	14.55	1.67	1.40	1.67	9.23	9.44	0.70	64.31
Tafo	0.03	5.12	7.67	5.54	8.76	16.43	3.37	1.50	2.95	6.11	6.48	3.67	66.99

SUB-STATIONS.
ANNUAL RAINFALL IN INCHES.

Year.	Akwadum.	Nankese.	Koransang.	Kukua.	Adonkwanta.
1945	52.3	—	—	—	—
1946	44.07	39.98	42.53	45.84	45.01
1947	53.17	50.74	63.98	56.64	68.41
1948	52.69	36.53	46.20	49.19	64.31

APPENDIX II.

PUBLICATIONS.

- GOODALL, D. W. ... A quantitative study of the early development of the seedling cacao (*Theobroma Cacao*). *Annals of Botany: New Series*, Vol. XIII, No. 49, 1949.
- NICOL, J. ... Cacao Capsids and their Control. Report of the Cacao Conference, London, 54-58, 1948.
- NICOL, J. ... Les Insects du Cacaoyer. Translated into French by V. de Bellefroid. *Bulletin Agricole du Congo Belge*, Vol. XXXIX, No. 4, 779-802, 1948.
- POSNETTE, A. F. and STRICKLAND, A. H. Virus Diseases of Cacao in West Africa. III. Technique of Insect Transmission. *The Annals of Applied Biology*, Vol. 35, No. 1, 53-63, 1948.
- POSNETTE, A. F. and STRICKLAND, A. H. Parasitism of the Mealybug Vectors of Swollen-Shoot of Cacao. *Nature*, Vol. 63, No. 4, 133, 1949.
- STRICKLAND, A. H. ... Estimation of Insect Populations in the Field. Report of the 5th Commonwealth Entomological Conference, London, July, 1948.
- STRICKLAND, A. H. ... The Vectors of some West African Cacao Viruses. Report of the Cocoa Conference, London, 58-61, 1948.
- VOELCKER, O. J. ... West African Cacao Research Institute: Field Experiments. *Empire Journal of Experimental Agriculture*, Vol. XVI, No. 64, October, 1948.

WEST AFRICAN CACAO RESEARCH INSTITUTE
PUBLICATIONS.

ANNUAL REPORT, April, 1947, to March, 1948: Published by the Crown Agents for the Colonies.

QUARTERLY REPORTS—Cyclostyled:

Sixteenth Quarterly Report, April to June, 1948.

Seventeenth Quarterly Report, July to September, 1948.

Eighteenth Quarterly Report, October to December, 1948.

Nineteenth Quarterly Report, January to March, 1949.

APPENDIX III. FINANCIAL STATEMENT.

LIABILITIES.			ASSETS.		
	£	s. d.		£	s. d.
SURPLUS AND DEFICIT ACCOUNT:—			BUILDINGS:—		
Accumulated Surplus	...	...	As per revaluation at 31st March, 1949	...	145,423 0 0
	...	...	Less: Amounts written off	...	145,423 0 0
DEPRECIATION FUND:—					
Motor Vehicles	...	£2,550 6 8	FURNITURE EQUIPMENT at cost	...	20,688 0 0
General Equipment	...	383 10 11	Less: Amounts written off	...	20,688 0 0
			SUNDRY DEBTORS:—		
			Staff Advances	...	1,533 9 3
			Staff Subsidies	...	941 17 6
			Gold Coast Government	...	141 2 10
			Department of Agriculture	...	341 15 10
			Stores at cost:—		2,958 5 5
			Timber	...	750 0 5
			Sundry Building Materials	...	1,051 4 9
			INVESTMENTS at cost	...	1,801 5 2
			(Market value £1,747,416 16s. 1d.)	...	1,771,096 2 5
			POST OFFICE SAVINGS BANK DEPOSIT	...	2,943 17 7
			CASH:—		
			In Hand—Imprest Account	...	200 0 0
			At Bank of British West Africa Ltd.	...	1,520 0 6
			Westminster Bank Ltd.—Deposit	...	8,000 0 0
			Crown Agents for the Colonies Account	...	16,102 15 0
					25,822 15 6
Carried forward	...	...			
					£1,804,622 6 1

SGD. O. J. VOELCKER,
DIRECTOR OF CACAO RESEARCH.

We have audited the above Balance Sheet of the West African Cacao Research Institute with the books and vouchers of the Institute and have obtained all the information and explanation that we have required. In our opinion and subject to our Report of even date attached hereto this Balance Sheet sets forth a true and correct view of the financial position of the Institute as at 31st March, 1949, according to the best of our information and the explanations given to us and as shown by the books of the Institute.

KUMASI,
27th September, 1949.

SGD. CASSELTON ELLIOTT & CO.,
Auditors.

